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SELENIUM MONITORING RESULTS: TRUSCOTT BRINE LAKE, TX AND ASSOCIATED BRINE COLLECTION AREAS, 1997-1998

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EXECUTIVE SUMMARY

This report presents results of a two-year study designed to evaluate selenium (Se) concentrations in a variety of environmental media at Truscott Brine Lake, TX and associated brine collection areas. The study was conducted by the Tulsa District, U.S. Army Corps of Engineers as part of comprehensive environmental monitoring efforts associated with the District's Wichita River Chloride Control Project (a portion of the former Red River Chloride Control Project, Oklahoma and Texas). Concerns exist over potential Se-related impacts associated with certain features of the project owing to naturally-elevated Se in soils and surface waters of the project area as well as the use of total evaporation lakes for brine disposal.

Objectives of the study were to define Se concentrations in a variety of environmental media at the existing brine disposal lake (Truscott Brine Lake, TX) and its associated brine collection facility (Area VIII on the South Fork of the Wichita River) during 1997 and 1998. In addition, limited data were collected at a second, partially-completed brine collection facility (Area X on the Middle Fork of the Wichita River) designed to ultimately convey brine waters to Truscott Lake. Associated with this overall objective were complementary goals of determining temporal trends in Se dynamics, establishing site-specific Se-related relationships among abiotic and biotic system components, and evaluating Se concentrations relative to established levels of concern.

This study consisted of several key components: (1) collection of surface water and sediments for Se analyses at project facilities; (2) collection and analysis of common avian prey items (e.g. fish) for Se analyses; (3) an intensive, two-year bird survey with an emphasis on semi-aquatic breeding birds; (4) documentation of nesting bird species and collection and analysis of avian eggs, liver samples, and ingested food items; and (5) comparison of current selenium concentrations in all media with published levels of environmental concern. Sampling locations, methodology, results, conclusions, and recommendations for further monitoring are presented in this report.

As a quick reference to summary statistics for Se concentrations measured in a variety of environmental media at various project locations, the following tables can be consulted: Truscott Brine Lake (Table 5.3-1, p. 67), Area VIII (Table 5.4-1, p. 73), and Area X (Table 5.5-1, p. 76).

Based on results of selenium monitoring activities during 1997 and 1998 at Truscott Brine Lake and associated brine collection areas, the following overall conclusions and recommendations were provided:

(1) Following approximately eleven (11) years of project operation, selenium concentrations in samples of water, sediment, fish, and limited samples of aquatic vegetation from Truscott Brine Lake were at or below "background" concentrations

typical for these media in Se-normal environments as well as below published threshold levels for protection of avian species. Similarly, Se concentrations in samples of eggs, livers, and ingested food of sedentary insectivorous birds (red-winged blackbirds) approximated background concentrations and were below threshold values established in the literature as protective of reproductive effects. For mobile piscivorous birds (great blue herons and double-crested cormorants), Se concentrations in eggs were higher with concentrations in some eggs exceeding both background concentrations and reproductive impairment threshold levels. While not the most appropriate species for Se impact evaluation owing to their mobility, these birds were the only piscivorous species observed nesting at Truscott Lake. Evaluation of limited Se concentration data from aquatic environments surrounding Truscott Lake, where naturally-occurring concentrations were much higher, provided a conceivable explanation for elevated Se concentrations in eggs of mobile bird species nesting at the impoundment. Based on these findings, it is possible that Truscott Lake provided Se-related benefits to populations of mobile avian species feeding both in the lake and in surrounding environments where concentrations were elevated. As long as these trends continue, Truscott Lake may provide future Se-related benefits to some populations of avian species in the project area.

(2) While extensive bird use surveys over a two year period revealed that while Truscott Lake and the surrounding area received use by a wide variety of bird species, nesting by semi-aquatic birds was limited to only a few avian species. For these species, nest numbers were likewise limited. While certainly not the only Se-induced reproductive impact known to occur among birds, post-hatch monitoring of nestlings revealed no evidence of malformations characteristic of Se toxicity, even in nests of mobile piscivorous species with elevated Se concentrations in eggs.

(3) Results of monitoring at Truscott Brine lake are applicable for the monitoring period only and should not be interpreted to represent current or future conditions. The potential for increasing Se concentrations as the project progresses and complexities involved with Se dynamics are justification for continued monitoring of a variety of environmental media at Truscott Lake. This is particularly true if additional brine sources are added as input to the impoundment. This monitoring will provide an increased understanding of site-specific Se dynamics and permit future risk / impact assessment as the project progresses.

(4) Monitoring results at the one operational brine collection facility (Area VIII on the South Fork of the Wichita River) revealed that waterborne Se concentrations were above background at this location, below the range of concern for avian species, and near the low end of the range of concern for fish and wildlife via bioaccumulation. Selenium concentrations in water and fish were similar in the brine collection pool and a sampling site upstream of the facility. For fish, concentrations were lower downstream of the facility indicating that mass removal may be providing some downstream Se-related benefits. Extensive bird survey results over the two year monitoring period failed to identify any semi-aquatic nesting birds at the pump station – an indication that construction of the facility did

not provide a significant attractant for semi-aquatic breeding birds during the monitoring period.

(5) Limited monitoring results from a partially-constructed, potential future brine collection area (Area X on the Middle Fork of the Wichita River) revealed high Se concentrations in both water and fish at this location. Naturally-elevated Se concentrations at this location necessitate careful site-specific monitoring if construction of brine collection facilities is ever completed at Area X. This monitoring should be conducted to evaluate potential increases in Se concentrations in a variety of matrices as a result of brine collection and pumping activities. In addition, monitoring activities should evaluate potential increased use by avian species as a result of facility operation as current Se concentrations appear to be at levels that could potentially impact these species.

(6) As the project progresses, further monitoring of Se concentrations in a variety of environmental matrices is definitely warranted. Results of monitoring efforts described in this report should help guide future selenium monitoring efforts for the project.

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SELENIUM MONITORING RESULTS: TRUSCOTT BRINE LAKE, TX AND ASSOCIATED BRINE COLLECTION AREAS, 1997 – 1998

1.0 INTRODUCTION AND OBJECTIVES

1.1 Introduction. This report presents results of a two-year study designed to evaluate selenium (Se) concentrations in a variety of environmental media at Truscott Brine Lake, TX and associated brine collection areas. The study was conducted by the Tulsa District, U.S. Army Corps of Engineers as part of comprehensive environmental monitoring efforts associated with the District's Wichita River Chloride Control Project (a portion of the former Red River Chloride Control Project, Oklahoma and Texas). Concerns exist over potential Se-related impacts associated with certain features of the project owing to naturally-elevated Se in soils and surface waters of the project area as well as the use of total evaporation lakes for brine disposal. A rather extensive review of the existing selenium literature, preliminary Se data, and analysis of potential Se-related impacts associated with the entire Red River Chloride Control Project were provided in a previous report (USACE 1993a). In addition, potential for Se-related impacts at Truscott Lake with various future alternatives for chloride control in the Wichita River Basin are presented in USACE (2000). These references should be thoroughly reviewed for an understanding of Se-related issues for the project.

1.2 Objectives. Objectives of this study were to define current selenium levels in a variety of environmental media at the existing brine disposal lake (Truscott Brine Lake, TX) and its associated brine collection facility (Area VIII on the South Fork of the Wichita River). In addition, limited data were collected at a second, partially-completed brine collection facility (Area X on the Middle Fork of the Wichita River) designed to ultimately convey brine waters to Truscott Lake. Associated with this overall objective were complementary goals of determining temporal trends in Se dynamics, establishing site-specific Se-related relationships among abiotic and biotic system components, and evaluating Se concentrations relative to established levels of concern. A major objective of the study was likewise to quantify current avian use of project facilities. It is anticipated that these data will not only define current selenium conditions at project facilities, but will also serve as initial baseline information for future Se monitoring efforts.

At the time of monitoring efforts for this study, future development of brine collection facilities at Area VII on the North Fork of the Wichita River was suspended as brines collected at this area were destined for disposal at proposed Crowell Brine Lake, TX. Accordingly, this monitoring effort did not include data collection at Area VII. Subsequent to completion of monitoring efforts described in this report, project design changes incorporating brine transport from Area VII to Truscott Brine Lake are being considered. While not a part of this monitoring study, analyses for water have been historically conducted at Area VII by both the Tulsa District and the USGS. Results of these analyses can be found in USACE (2000).

It is important to note that Truscott Lake is authorized and designed solely for disposal of naturally-occurring brine waters. In contrast to most other Corps reservoir projects operated for multiple project purposes, Truscott Lake authorization does not necessitate maintenance of diverse communities of exclusively aquatic species (i.e., plankton, invertebrates, fish assemblages). However, environmental concerns are associated with protection and potential impacts on semi-aquatic organisms which may frequent the lake for feeding, breeding, or resting activities. As impaired avian reproduction and embryonic development are frequently the first biological indication of selenium contamination problems in aquatic systems (Lemly and Smith 1987), data collection for this study was designed to support evaluation of potential impacts on semi-aquatic birds.

1.3 Summary of Activities. The study consisted of several key components: (1) collection of surface water and sediments for Se analyses at project facilities; (2) collection and analysis of common avian prey items (e.g. fish) for Se analyses; (3) an intensive, two-year bird survey with an emphasis on semi-aquatic breeding birds; (4) documentation of nesting bird species and collection and analysis of avian eggs, liver samples, and ingested food items; and (5) comparison of current selenium concentrations in all media with published levels of environmental concern. Sampling locations, methodology, results, conclusions, and recommendations for further monitoring are presented in subsequent sections of this report.

1.4 Report Organization. This report is organized by major sections of text describing key components of the study. For ease of reading, cited figures and tables for each section appear collectively at the end of the section. Raw data and related information are attached as appendices at the back of the document.

2.0 DESCRIPTION OF PROJECT AREAS AND FACILITIES

2.1 General. Complete descriptions of overall project objectives, goals, features, and environmental aspects of chloride control activities can be found in past documentation for the project (USACE Tulsa District 1976, 1993b). These documents should be consulted for an understanding of overall project aspects. Descriptions of facilities pertinent to Se evaluations for this study are presented in this section.

2.2 Truscott Brine Lake, TX. Truscott Brine Dam is located at river mile 3.6 on Bluff Creek, a tributary of the North Fork of the Wichita River, approximately 3 miles northwest of Truscott in Knox County, Texas (Figure 2.2-1). The embankment is an earth-filled structure 15,500 feet long and was completed in December 1982. The lake began receiving brines inputs in May 1987. The lake drains a 26.2-square-mile area (primarily undeveloped and agricultural lands), currently receives brine input from collection facilities at Area VIII (Bateman Pump Station), and may potentially receive brines collected at other areas (Figure 2.2-1) in the future. As originally designed, at the top of the brine storage pool (elevation 1,499 ft and representing 100 years accumulation of brine and sediment), the lake is anticipated to have a surface area of 2,980 acres, a capacity of 107,000 acre-feet, and an average depth of 36 feet. The lake is designed for total retention of brines with evaporative reduction in brine volume and has no outlet works for controlled water releases.

During the sampling period for this study (February 1997 to September 1998), Truscott Lake surface elevation was relatively stable at around 1471 ft. (448.36 m). At this elevation, the lake has an approximate volume of 40,125 acre-ft (4.95E07 m^3) and a surface area of 1,800 acres (7.28E06 m^2). Rainfall totals at Truscott Lake were 33.7 inches (85.6 cm) and 20.1 inches (51.1 cm) for 1997 and 1998, respectively. Thus, considerable differences existed between the two years with 1998 being much dryer and hotter relative to 1997.

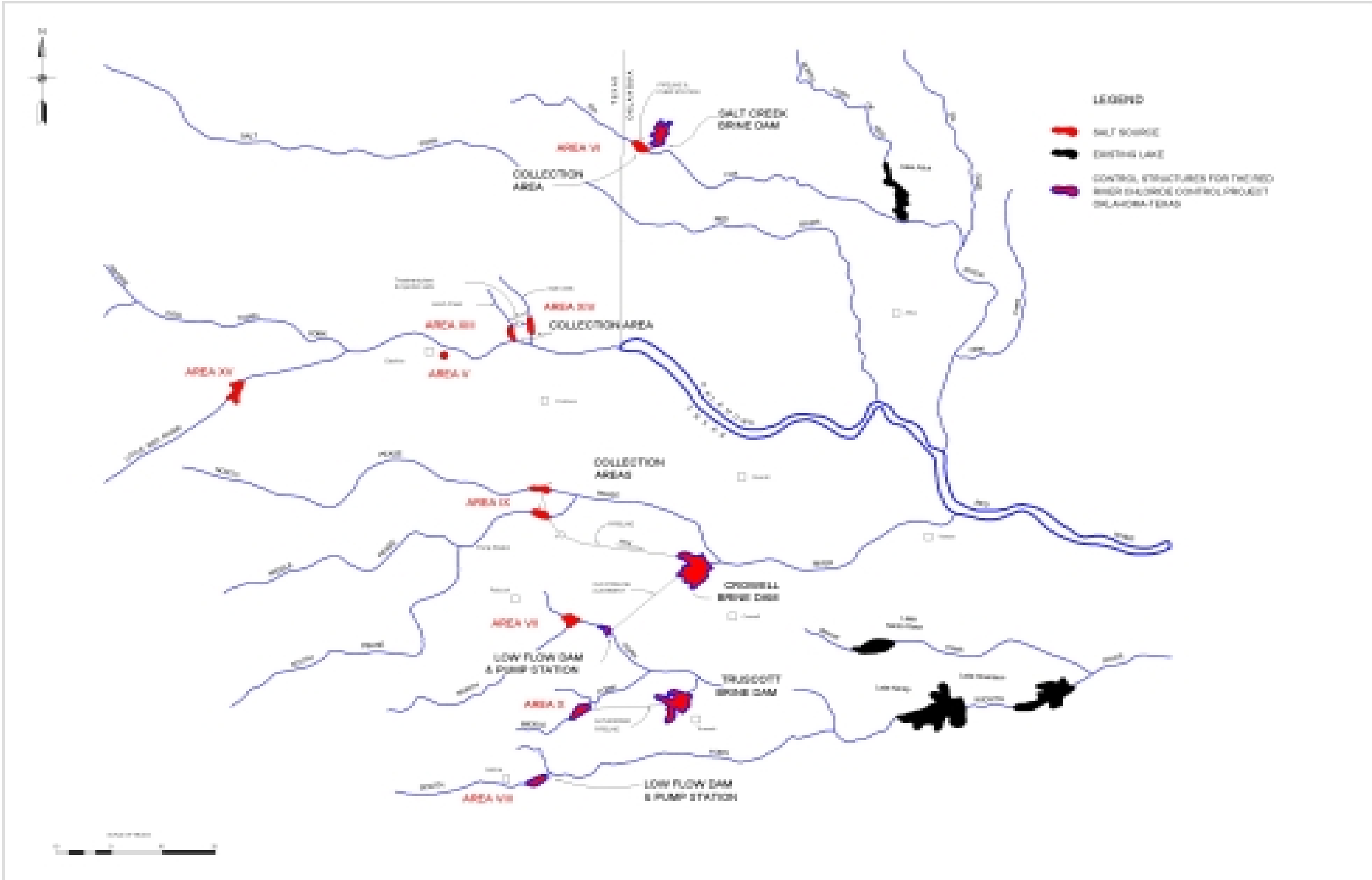

Figure 2.2-1. Chloride control project area.

2.3 Freshwater Ponds. Two freshwater ponds exist approximately 0.5 mile (800 m) west of the upper end of Truscott Brine Lake. The northernmost pond has an estimated surface area of 80 acres while the southern pond covers approximately 10 to 12 acres. These ponds were constructed to reduce freshwater inflows to Truscott Brine Lake, are hydraulically separated from the lake, and are therefore not influenced by brine inflows. Accordingly, these ponds were occasionally sampled as reference or “control” areas (see next section).

2.4 Area VIII (Bateman Pump Station). Brine inputs to Truscott Lake are currently transported via pipeline from collection facilities at Area VIII, located at river mile 74.9 of the South Fork of the Wichita River about five miles east of Guthrie, Texas (Figure 2.2-1). During the study period (and at date of this report) Area VIII was the only fully-constructed brine collection area and was the sole source area for brines transported to Truscott Lake.

Collection facilities consist of a deflatable fabric weir extending across the existing stream channel. The weir is 5 feet high, 49 feet long, and impounds a 31-acre pool with a capacity of 83 acre-feet. At low flow, waters are pumped from the impounded pool, transported via pipeline, and discharged to Bluff Creek at the upper end of Truscott Brine Lake. At high river flows, the weir is deflated for passage of lower chloride waters.

2.5 Area X (Lowrance Pump Station). Area X is located at river mile 20.5 on the Middle Fork of the Wichita River (Figure 2.2-1). Brine would be collected through use of a low-flow dam with a 5-foot-high inflatable weir identical to that described for Area VIII. Collected brine would be pumped via pipeline to Truscott Brine Lake for permanent storage. At the time of this study (and at date of this report), collection facilities at Area X had been completed, but no pipeline had been constructed pending further evaluation of brine collection alternatives in the basin. Accordingly, the Lowrance Pump station was not operational and relatively normal river conditions existed during sampling events.

3.0 STUDY METHODOLOGY

3.1 General. In general, study design and methodology used in this evaluation were those developed during 1996 by a State and Federal interagency workgroup tasked with preparing an environmental monitoring plan for evaluating potential selenium-related impacts associated with the entire Red River Chloride Control Project. While never formally adopted, a draft plan prepared by this group for collecting baseline Se information at existing portions of the project formed the general basis for this study. It was the consensus of this group that general baseline Se information (e.g. spatial and temporal Se variation in environmental media at Truscott Lake and brine collection facilities) was needed prior to development of a complete monitoring plan. While baseline data collection was originally designed for a one-year period, data collection for a period of two years for this study was possible owing to chloride control project delays. Detailed descriptions of sampling sites, environmental media, and sampling methods are presented below.

3.2 Truscott Brine Lake, TX. Data collection activities at Truscott Lake are described in this section. Details are provided separately for each environmental medium.

3.2.1 Water. Water samples for Se analyses were initially collected at three (3) sampling sites at Truscott Lake. Sites 1 through 3 represented sampling stations near Truscott Dam, at mid-lake, and near the upper end of the lake, respectively. A fourth sampling site (Site 4) was later added at the extreme upper end of the impoundment near the area of brine inflows as a shallow, near-shore station. Sampling sites are shown in Figure 3.2.1-1. Approximate coordinates recorded by global positioning system (GPS) for each sampling station were as follows:

Site 1: 33 47.705N
99 50.082W
Site 2: 33 47.344N
99 50.811W

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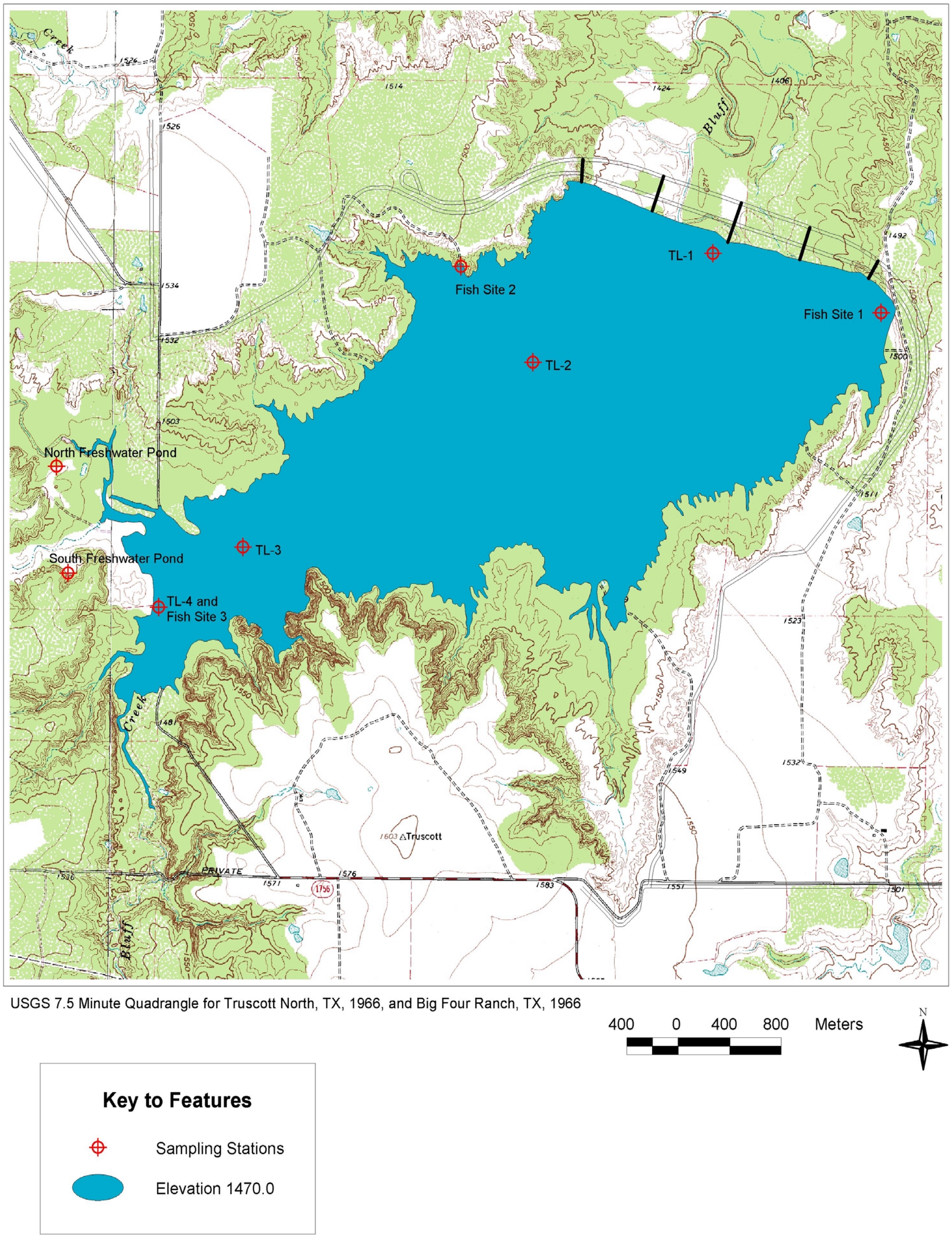


FIGURE 3.2.1-1
SAMPLING LOCATIONS, TRUSCOTT LAKE, TEXAS

Site 3: 33 46.732N
99 51.985W
Site 4: 33 46.533N
99 52.326W.

On 25 March and 22 April 1997, water samples were collected from two diked areas on Bluff Creek above Truscott Lake. Initially designed to pond water to enhance evaporation, these dikes were washed out by high flows during the spring of 1997. These areas were not rebuilt and were consequently abandoned as sampling sites for the remainder of the study.

Water samples from Truscott Lake were collected on twelve (12) dates between February 1997 and September 1998. Sampling dates in 1997 included the following: 26 February, 25 March, 23 April, 10 June, 14 July, 26 August, 22 October, and 15 December. For 1998, sampling dates were 26 January, 30 April, 7 July, and 2 September. These sampling dates allowed water sample collection over two years during periods of thermal stratification as well as periods when the lake was vertically mixed.

At sampling Sites 1 and 2, water samples were collected at two depths on all dates. Surface samples were collected at a depth of approximately 0.5 m while samples at depth were collected approximately 1 m above the sediments. As vertical stratification was never observed at Sites 3 and 4, only surface samples were collected at these shallow water locations. For QA/QC purposes, water samples were collected in triplicate on each sampling trip at an approximate frequency of 10 percent. Overall, eighty-seven (87) water samples were collected from Truscott Lake during the study. All water samples were collected in pre-cleaned (USEPA Level 1) polyethylene containers and immediately preserved with concentrated nitric acid. Samples were transported from the field on ice and stored under refrigeration pending analysis. Samples were documented and accompanied by signed chain-of-custody from collection to submission to the analytical laboratory.

Primary field samples and QC duplicates were analyzed by the U.S. Geological Survey (USGS) National Water Quality Laboratory, Arvada, Colorado. Total (unfiltered) selenium analyses were performed using EPA Method 7742 (hydride generation) with a resulting quantitation limit of 1 ug/l (ppb). As preliminary data indicated that total Se concentrations were below analytical quantitation limits (see results), it was unnecessary to determine dissolved Se concentrations (from filtered samples). Quality assurance samples resulting from triplicate sampling on each date were analyzed separately by an independent laboratory -- Environmental Trace Substances Laboratory (ETSL), Rolla, Missouri. This lab reported quantitation limits of 0.5 ug/l total Se.

3.2.2 Sediments. Sediment samples were collected at Truscott Lake on 26 August 1997 and 7 July 1998. In 1997, sediments were collected at sampling Sites 1 through 3 and an intermediate location between Sites 2 and 3 (designated as Site 2.5). In 1998, samples were collected at Sites 1, 2, 2.5, and 4. Sediment sampling was not possible at Site 3 on this date owing to dense mats of vegetation covering the lake bottom. Sediment sampling was intentionally conducted both years when vertical stratification had developed at deep water sites. Reduced conditions favor Se speciation to more insoluble forms (Masscheleyn et al. 1990, 1991) that would tend to accumulate in sediments and form "worst-case" concentrations at these times.

Sediment samples were collected with an Eckman dredge and samples placed in pre-cleaned polyethylene containers. Sediment materials ranging in depth from 1 to 8 cm from the sediment surface (with depths documented for each sample) were collected depending upon availability and nature of bed materials. Experimental evidence seems to indicate that selenium cycling processes are confined to the upper few (0 to 8) cm of aquatic sediments (Rudd et al. 1980, Oremland et al. 1989, Oremland et al. 1990). Sedimentation rates appear to be fairly low in Truscott Lake and location of sediments sufficient for sampling was difficult at times. This resulted in variation in depths for sediment samples.

Upon collection, sediment samples were placed on dry ice and frozen pending laboratory analysis for total Se. Samples collected in 1997 were split between the USGS National Lab and ETSL while all sediment samples collected in 1998 were analyzed by ETSL. For 1997 samples, analyses also included total organic carbon (TOC). Subsamples were likewise archived for future analysis of grain size. Samples were accompanied by signed chain-of-custody from collection to submission to analytical labs.

3.2.3 Physicochemical Field Parameters. Vertical profiles of field water quality parameters (water temperature, pH, dissolved oxygen, conductivity, total dissolved solids) were collected at 1 m depth intervals at Truscott Lake Sites 1 and 2 using a Hydrolab Surveyor II data instrument. This instrument was calibrated according to the manufacturer's instructions prior to each sampling event. Surface readings (0.5 m) only were recorded at Sites 3 and 4 owing to shallow water depths at these locations.

3.2.4 Fish. Truscott Lake fish for Se analyses were collected by Tulsa District personnel on 10 June 1997 and 7 July 1998 by shoreline seining techniques at three locations: near the east end of Truscott Dam (designated as Fish Collection Site 1), at approximately mid-lake on the west side of the impoundment (Fish Site 2), and at the extreme upper end of the lake (Fish Site 3) near water quality sampling Site 4 (Figure 3.2.1-1). Approximate coordinates as recorded by GPS were as follows:

Fish Site 1:	33 47.516N
	99 49.397W
Fish Site 2:	33 47.656N
	99 51.107W
Fish Site 3:	33 46.533N
	99 52.326W.

Fish collected by seining during both years were limited to only two species: the Red River pupfish (*Cyprinodon rubrofluviatilis*) and plains killifish (*Fundulus zebrinus*). An attempt was made to obtain fish of varying size ranges of both species at each sampling site. Likewise, an attempt was made to collect approximately the same number of fish from each sampling location. In all, 27 fish were collected from Truscott Lake in

1997 while 32 were collected in 1998. Upon collection, fish were rinsed in lake water only, placed in pre-cleaned sample containers labeled by station, transported to the lab on dry ice, and stored frozen pending analysis. Samples were accompanied by signed chain-of-custody from collection to submission to the analytical lab.

Fish samples were prepared individually (without compositing) for total selenium analysis on a wholebody basis. Total length (mm) and weight (g) for each individual were recorded and each fish placed in a 40 ml pre-cleaned vial. For plains killifish, sex of individuals was recorded by examination of genital orifices using methods described by Sublette et al. (1990). No attempt was made to determine sex of Red River pupfish. Analyses for percent moisture and total selenium for all fish were conducted by ETSL and selenium results reported as parts per million (ppm) on a dry weight basis.

3.2.5 Aquatic Invertebrates. During both years of the study, an attempt was made to collect and analyze samples of aquatic invertebrates representing a potential food source for insectivorous birds. Sampling methods included examination of sediments obtained by dredge sampling as well as visual examination of substrate (woody debris, rocks, vegetation) for invertebrates of sufficient mass for Se analysis. Despite these attempts, no suitable invertebrates could be located. Accordingly, no invertebrate samples were collected during the investigation.

3.2.6 Aquatic Vegetation. While not the central focus of this study, very limited (n = 3) samples of aquatic vegetation were collected on 7 July 1998 from the upper end of Truscott Lake and analyzed for total Se. Included were two (2) samples of widgeon grass (*Ruppia* sp.) which grows prolifically in the upper end of the impoundment and one sample of *Chara* sp.. Total Se results were reported as ppm dry weight.

3.2.7 Bird Use Surveys. A primary focus of this study was an evaluation of avian use dynamics associated with Truscott Lake and the potential for selenium-related impacts on birds present at the impoundment. Accordingly, an intensive, two-year bird survey was conducted by researchers from Texas Tech University, Lubbock, under contract to the Tulsa District. Objectives of the survey were to document and quantify seasonal bird use at Truscott Lake, identify species most suitable for selenium evaluations, and locate nests of appropriate breeding species for subsequent bird egg sampling and selenium analyses. Complete details of methodology used in these surveys are presented in the final survey report included as Appendix A.

3.2.8 Bird Egg Sampling. A key component of this study was quantification of selenium levels in eggs of appropriate bird species breeding in the vicinity of Truscott Lake. Avian eggs are one of the best biotic matrices for Se-related risk and impact analyses and provide the most precise and reliable means of evaluating reproductive impacts (Skorupa et al. 1996, Lemly 1993, Skorupa and Ohlendorf 1991). The most appropriate birds for egg analyses are sedentary species (e.g. grebes) which spend the majority of their time foraging in a localized environment and are therefore closely tied to the aquatic environment via food chain dynamics (Skorupa and Ohlendorf 1991). It was the intent of this study to collect and analyze eggs from both an appropriate piscivorous and insectivorous bird species.

Bird eggs for Se analysis were collected at Truscott Brine Lake during May and early June of 1997 and late April through early June of 1998. While complete results of breeding bird surveys are presented in Appendix A and summarized in the next section, generalized findings of these surveys were that very few semi-aquatic bird species were observed nesting around Truscott Lake. Most significantly, no sedentary piscivorous species and only one semi-aquatic insectivorous bird species which feeds in a relatively localized area were noted nesting in the area. Accordingly, it was not possible to collect eggs from the most desirable bird species typically chosen for Se evaluations. Eggs were, however, collected from nests of the only semi-aquatic species found nesting in the area: the great blue heron (*Ardea herodias*), double-crested cormorant (*Phalacrocorax auritus*) (both piscivores), and red-winged blackbird (*Agelaius phoeniceus*), an insectivore during the breeding season (Hintz and Dyer 1970).

A single egg was randomly collected from each nest. Nest locations can be found in the final bird census report (Appendix A). For 1997, a total of twenty-five (25) eggs were collected at Truscott Lake (seven heron, six cormorant, and 12 red-winged blackbird). In 1998, a total of twenty (20) eggs were collected (seven heron, eight cormorant, and five red-winged blackbird). Upon collection, eggs were bubble-wrapped for protection, placed on ice, and immediately taken to the Truscott Lake project office for processing. Egg measurements included length, width, and total weight. Following measurement, egg exteriors were washed with deionized water. The air sac end of the shell was removed with a scalpel or razor blade and egg contents transferred to a pre-cleaned jar. A rough estimate of bird embryonic development was recorded and egg contents weight determined by difference in weight of tare-weighed jars and that of jar and contents. Custody seals were placed across lids of all egg samples and samples were accompanied by signed chain-of-custody from collection to submission to the analytical laboratory. Egg samples were stored frozen and always transported and shipped on dry ice. Analyses for percent moisture and total selenium were performed by ETSL with Se results reported as ppm dry weight.

3.2.9 Bird Livers and Ingested Food Samples. Adult female red-winged blackbirds were collected by TTU personnel by shotgun utilizing steel shot at Truscott Lake on 9 July of both 1997 and 1998. Three (3) birds were collected in 1997 and five (5) in 1998. Livers were removed from all birds and stored frozen pending analysis. In 1997 only, ingested food samples were obtained from the esophagus and gizzard of collected birds and submitted for analysis. Liver and food samples were analyzed for moisture content and total Se by ETSL with Se results reported as ppm dry weight.

3.3 Freshwater Ponds. Samples of several environmental media were occasionally collected at the freshwater ponds west of the upper end of Truscott Lake (Figure 3.2.1-1). While not a critical part of the study, these data were collected for potential estimation of selenium concentrations in environments not impacted by brine storage. Details are described below.

3.3.1 Water. Surface (0.5 m depth) water samples for total Se analyses were collected at both freshwater ponds on 26 March, 22 April, and 11 June 1997. As concentrations were all below analytical detection limits (see next section) and not expected to drastically change, no additional water samples were collected from these ponds. Samples were analyzed for total Se in an identical manner to those from Truscott Lake.

3.3.2 Bird Eggs. Red-winged blackbird eggs were collected at the freshwater ponds during both 1997 and 1998 breeding seasons. Identical sampling and analysis methods employed for egg sampling at Truscott Lake were used. Eight (8) eggs were collected in 1997 while seven (7) were collected in 1998.

3.3.3 Bird Livers / Ingested Food Samples. Adult female red-winged blackbirds were collected by TTU personnel at the freshwater ponds on 9 July of both 1997 and 1998 for liver and ingested food (1997 only) Se analyses. Five (5) birds were collected during both 1997 and 1998. Livers and food samples were handled and analyzed in an identical manner to those from Truscott Lake.

3.3.4 Fish. Fish for Se analysis were not collected from the freshwater ponds. Fish assemblages in these ponds are most likely dominated by sunfishes and other species adapted to lower salinity conditions and would therefore be considerably different from those inhabiting saline Truscott Lake.

3.4 Area VIII (Bateman Pump Station). Sampling locations, environmental media, and sampling methods employed at Area VIII are described in this section.

3.4.1 Sampling locations. A primary objective of environmental sampling at the Bateman Pump Station was to determine if brine collection activities were resulting in increased Se concentrations in abiotic or biological matrices at the collection facility. Pumping rates from the collection facility are closely matched to inflow rates to ensure maintenance of a stable pool. In terms of mass balance (and assuming a completely mixed pool), it would seem that this practice would not result in increased materials concentrations in the impounded pool as mass removal via pumping should approximate upstream inputs. Sampling locations were chosen to evaluate this assumption.

Three sampling locations were employed at the Area VIII pump station: (1) an upstream site located approximately 0.4 miles (0.7 km) upstream of the weir and collection pool where conditions appear riverine, (2) a site immediately upstream of the collection weir in the pooled area formed by the inflated dam, and (3) a location approximately 225 ft (70 m) downstream of the collection pool. Designations of “U”, “P”, and “D” were used in sample identification numbers to designate upstream, pool, and downstream locations, respectively. Sampling was conducted only when the dam was inflated and a stable pool present.

3.4.2 Water. Water samples were collected at all three Area VIII sampling stations described above on ten (10) dates during the study. These dates included 25 March, 22 April, 10 June, 14 July, 26 August, and 17 December, 1997. Sampling dates in 1998 were 26 January, 30 April, 6 June, and 2 September. Samples were collected from mid-channel at a depth of 0.5 m and analyzed for total selenium. Analytical methods, preservatives, and laboratories were those previously described for Truscott Lake water samples.

3.4.3 Sediment. Minimal sediment samples were collected at the Bateman Pump Station for this study. Sediment analyses and interpretation are complicated by extreme variation in sediment type among sampling sites, intra-site sediment patchiness, and continually changing sediment conditions with variations in river discharge (e.g. high flow events). Accordingly, limited sediment samples were collected as a very general measure of selenium concentrations in bed materials.

A single sediment sample was collected from the Area VIII collection pool on 26 August 1997. In 1998, sediment samples were collected from all three Area VIII sampling sites on 6 July. Samples were analyzed for selenium as previously described for Truscott Lake sediments with results reported as mg/Kg (ppm) total Se on a dry weight basis.

3.4.4 Fish. An important part of this study was collection of fish from the Area VIII collection facility for selenium analysis. Fish from all three Area VIII sampling sites (described above) were collected by seine on 10 June 1997 and 6 July 1998. Fish collected by seining during both years were limited to only two species: the Red River pupfish (*Cyprinodon rubrofluviatilis*) and the plains killifish (*Fundulus zebrinus*). Both species were collected in the brine collection pool and at the sampling site downstream of the Bateman Pump Station. While pupfish were abundant, no plains killifish were collected in repeated seine hauls at the upstream site during either year. Slight habitat differences may have been responsible for absence of this species at this site.

Ten (10) individuals of each fish species present were collected at each sampling site during both 1997 and 1998. Accordingly, 10 pupfish and 10 killifish were collected from the brine collection pool and downstream site on each sampling date, while 10 pupfish only were obtained from the upstream sampling location. An attempt was made to obtain fish of varying size ranges of both species. In all, 100 individual fish were collected and analyzed over the two year study. Upon collection, fish were rinsed in river water only, placed in pre-cleaned sample containers labeled by station, transported to the lab on dry ice, and stored frozen pending analysis. Samples were accompanied by signed chain-of-custody from collection to submission to the analytical lab.

Fish samples were prepared individually (without compositing) for total selenium analysis on a wholebody basis. Total length (mm) and weight (g) for each individual were recorded and each fish placed in a 40 ml pre-cleaned vial. For plains killifish, sex of individuals was recorded by examination of genital orifices using methods described by Sublette et al. (1990). No attempt was made to determine sex of Red River pupfish.

Analyses for percent moisture and total selenium for all fish were conducted by ETSL and selenium results reported as ppm on a dry weight basis.

3.4.5 Aquatic Invertebrates. During both years of the study, an attempt was made to collect benthic invertebrates of sufficient mass for selenium analyses from sampling sites at Area VIII. Sampling methods included examination of collected sediments as well as visual examination of in-stream substrate (which is limited mainly to rocks). Despite these attempts, suitable invertebrates could not be found. Accordingly, no invertebrate samples were collected during the study. A similar scarcity of suitable invertebrates was noted at Truscott Lake.

3.4.6 Bird Use Surveys. Similar to activities at Truscott Lake, a primary focus of this study was evaluation of avian use dynamics associated with the brine collection facility at Area VIII and the potential for selenium-related impacts on birds. Conceivably, selenium-related impacts could occur if selenium concentrations in environmental media were elevated by collection activities or if operation of the facility resulted in increased attraction and use by semi-aquatic birds. In an attempt to quantify bird use, a two-year bird survey at Area VIII similar to the one described for Truscott Lake was conducted by researchers from Texas Tech University, Lubbock. Objectives of the survey were to document and quantify seasonal bird use at the collection facility, identify species most suitable for selenium evaluations, and locate nests of appropriate breeding species for subsequent bird egg sampling and selenium analyses. Complete details of methodology used in these surveys are presented in the final survey report included as Appendix A.

3.4.7 Bird Egg Sampling. While complete bird survey results at Area VIII are presented in Appendix A and summarized in the next section, general findings relative to breeding birds for both years were that no semi-aquatic birds were observed nesting in the vicinity of the Bateman Pump Station. Consequently, nesting bird use was determined to be extremely minimal and it was not possible to collect bird eggs for Se analysis at this location.

3.4.8 Physicochemical Field Parameters. Measurements of field water quality parameters including water temperature, pH, dissolved oxygen, conductivity, and total dissolved solids (by probe) were recorded at all three Area VIII sampling sites on most sampling dates. Measurements were recorded with a Hydrolab Surveyor II data instrument which was calibrated according to the manufacturer's instructions prior to each sampling event. All readings were taken at 0.5 m depth.

3.5 Area X (Lowrance Pump Station). Very limited data were collected at brine collection Area X, the Lowrance Pump Station. As previously noted, this area is partially completed and may serve as a future, additional brine source for Truscott Lake. As the facility is not operational, all samples were collected at a single site near the location of the inflatable dam.

3.5.1 Water. Two water samples for total selenium analysis were collected at Area X as a part of this study. Samples were collected on 26 February 1997 and 7 July 1998. Samples were collected, preserved, and analyzed in the same manner as those from other areas.

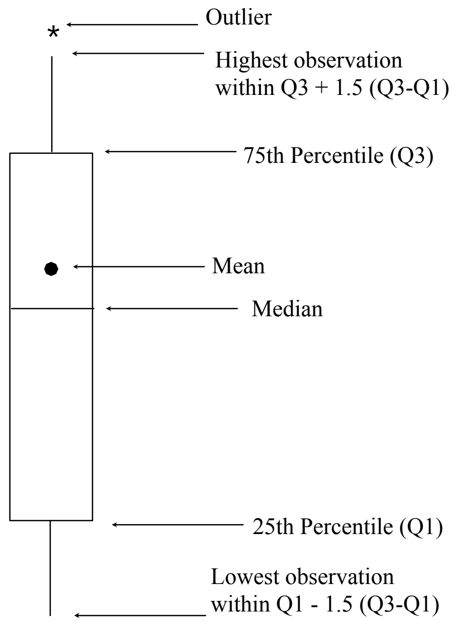
3.5.2 Fish. Thirteen (13) fish from four (4) species were collected at Area X on 7 July 1998 and analyzed for total selenium. Preliminary water analyses indicated that this area is considerably higher in total waterborne selenium than other project locations and fish were analyzed from this area as a measure of bioaccumulation potential for these conditions. Chloride concentrations at Area X are considerably less that those at other project locations – a condition which is most likely responsible for slightly increased diversity in fish assemblages. Fish samples consisted of four (4) Red River pupfish, three (3) plains killifish, three (3) red shiners (*Cyprinella lutrensis*) and three (3) plains minnows (*Hybognathus placitus*). Fish were collected, sorted, stored, and analyzed in a manner consistent with methods employed at other locations.

3.6 Quality Assurance / Quality Control Measures. In addition to collection of triplicate water samples for Se analyses by independent labs, additional QA / QC analyses were conducted in association with biological samples. These included analysis of blank samples, duplicate analyses of biological samples, matrix spike analyses, and analysis of reference samples of biological materials.

3.7 USGS Sampling at Brine Collection Facilities. While not a direct part of this study, water sample analyses have also been conducted by the USGS at all potential brine collection areas in the Wichita River Basin (Figure 2.2-1), including Areas VIII and X. As a part of this effort, both total and dissolved selenium analyses have been conducted on an approximate monthly basis at these areas. A brief discussion of these findings for the monitoring period is included in this report as these data provide additional information regarding selenium concentrations at various existing and potential project areas. A summary of water analyses at project brine collection areas is likewise provided in USACE (2000).

3.8 Statistical Analyses and Data Presentation. Statistical analyses for this study were conducted using Minitab® Release 12 statistical software (Minitab, Inc. 1998). Initially, data distributions for each environmental matrix were evaluated separately using the Anderson-Darling Normality Test. Selenium data for most matrices were found to conform to a non-normal distribution (see individual results in the next section). Accordingly, nonparametric statistical tests were employed in analysis of all data (even those approximating a normal distribution) for the sake of consistency, increased statistical power for non-normal data, and a lack of reliance of these tests on any particular data distribution (Helsel and Hirsch 1995). Hypothesis testing between two groups was conducted using the Mann-Whitney test while comparisons among multiple groups was accomplished using analysis of variance (ANOVA) on ranked data. When differences among medians were detected using ANOVA on the ranks, Tukey's multiple comparison test was used to identify these differences. Spearman's rank correlation was used in all correlation analyses. A significance level of $\alpha = 0.05$ was used for all statistical analyses for this study.

Owing to their interpretive value, boxplots are used for presentation of most data for this study. As statistical packages vary in their construction of such plots, a generalized presentation of how boxplots for this study can be interpreted is provided below.



Results of hypothesis testing between groups (Mann-Whitney) or multiple comparison tests (Tukey's on ranked data) are depicted on boxplots for this study. Letters (e.g. A, B) to the right of boxplot median lines are used to depict these results. Groups sharing common letters are not significantly different at $\alpha = 0.05$.

4.0 RESULTS

4.1 General. Results of all monitoring activities are presented in this section. Results are presented separately for each project area and environmental medium.

4.2 Truscott Brine Lake, TX. Results of monitoring activities at Truscott Brine Lake are presented in this section. Details are provided separately for water, sediments, fish, aquatic vegetation, bird use surveys, bird eggs, bird livers, bird-ingested food items, and physicochemical parameters.

4.2.1 Water. Total selenium data for all Truscott Lake water samples collected for this study are presented in Table 4.2.1-1. Total selenium concentrations in all 66 primary field samples collected during both 1997 and 1998 at all Truscott Lake sampling sites were below analytical quantitation limits (ranging from 0.5 to 1 ug/l). Concentrations were likewise below quantitation limits in most all field duplicate and QA replicate samples though detectable concentrations of 0.6, 1, and 2.2 ug/l were reported on three occasions (Table 4.2.1-1). Agreement was generally good among replicate samples analyzed by independent laboratories. The last round of samples collected (2 September 1998) indicated that waterborne total Se concentrations across Truscott Lake were still less than the 0.5 ug/l detection limit after approximately 11 years of project operation.

TABLE 4.2.1-1

TRUSCOTT LAKE SELENIUM DATA (WATER)

Date	Time	Depth	Total Se (ug/l)	Duplicate	QA (ETSL)
		Site 1 (Near Dam)			
2/26/1997	1000	S	<1	<1	<0.5
2/26/1997	1000	B	<1		
3/25/1997	1330	S	<1		
3/25/1997	1330	B	<1		
4/23/1997	910	S	<1		
4/23/1997	910	B	<1		

			Table 4.2.1-1 (Continued)		
Date	**Time**	**Depth**	**Total Se (ug/l)**	**Duplicate**	**QA (ETSL)**
			Site 1 (cont.)		
6/10/1997	1337	S	<1		
6/10/1997	1337	B	<1		
7/14/1997	1355	S	<1	<1	<0.5
7/14/1997	1355	B	<1		
8/26/1997	1313	S	<1	<1	2.2
8/26/1997	1313	B	<1		
10/22/1997	1030	S	<1		
10/22/1997	1030	B	<1		
12/15/1997	1430	S	<1		
12/15/1997	1430	B	<1		
1/26/1998	1400	S	<1		
1/26/1998	1400	B	<1		
4/30/1998	1125	S	<1		
4/30/1998	1130	B	<1		
7/7/1998	931	S	<1		
7/7/1998	931	B	<1		
9/2/1998	1315	S	<0.5 (ETSL)	0.6 (ETSL)	
9/2/1998	1315	B	<0.5 (ETSL)		
			Site 2 (Mid-Lake)		
2/26/1997	1035	S	<1		
2/26/1997	1035	B	<1		
3/25/1997	1410	S	<1	<1	<0.5
3/25/1997	1410	B	<1		
4/23/1997	955	S	<1		
4/23/1997	955	B	<1		
6/10/1997	1410	S	<1		
6/10/1997	1410	B	<1		
7/14/1997	1415	S	<1		
7/14/1997	1415	B	<1		
8/26/1997	1405	S	<1		
8/26/1997	1405	B	<1		
10/22/1997	1040	S	<1		
10/22/1997	1040	B	<1		
12/15/1997	1447	S	<1	<1	1
12/15/1997	1447	B	<1		
1/26/1998	1440	S	<1		
1/26/1998	1440	B	<1		
4/30/1998	1150	B	<1		
7/7/1998	959	S	<1		
7/7/1998	959	B	<1		
9/2/1998	1340	S	<0.5 (ETSL)		
9/2/1998	1340	B	<0.5 (ETSL)		

Date	Time	Depth	Table 4.2.1-1 (Continued) Total Se (ug/l)	Duplicate	QA (ETSL)
		Site 3 (Upper End)			
2/26/1997	1055	S	<1		
3/25/1997	1440	S	<1		
4/23/1997	1020	S	<1	<1	<0.5
6/10/1997	1437	S	<1	<1	<0.5
7/14/1997	1445	S	<1		
8/26/1997	1445	S	<1		
10/22/1997	1055	S	<1	<1	<1
12/15/1997	1520	S	<1		
1/26/1998	1500	S	<1	<1	<1
4/30/1998	1205	S	<1	<1	<0.5
7/7/1998	1045	S	<1		
9/2/1998	1355	S	<0.5 (ETSL)		
		Site 4 (Extreme Upper End)			
6/10/1997	1500	S	<1		
7/14/1997	1456	S	<1		
12/15/1997	1540	S	<1		
1/26/1998	1515	S	<1		
4/30/1998	1215	S	<1		
7/7/1998	1055	S	<1		
9/2/1998	1405	S	<0.5 (ETSL)		

S = surface sample (0.5 m depth)
B = bottom sample (1 m from bottom)
Duplicate = duplicate sample analyzed by primary laboratory (USGS)
QA = quality assurance sample analyzed by separate laboratory (ETSL)
ETSL = Environmental Trace Substance Laboratory, Rolla, MO.

4.2.2 Sediments. Sediment data from Truscott Lake are presented in Table 4.2.2-1. Total selenium concentrations in sediments were low and ranged from below sample quantitation limits (< 0.4) to 0.58 mg/Kg (ppm) dry weight. While limited sample size precluded rigorous statistical analyses, no major differences were noted between years or among sampling sites for either year. In 1998, concentrations were slightly higher toward the upper end of the impoundment relative to those at near-dam sites (Table 4.2.2-1). Sediment total organic carbon concentrations ranged from around 1.2 to 5.9 percent by weight, the latter occurring near the upper end of Truscott Lake.

TABLE 4.2.2-1

TRUSCOTT LAKE SEDIMENT DATA
(mg/Kg dry weight)

Date	Time	Depth (cm)	Total Se	Total Se (Duplicate)	Total Organic Carbon
			Site 1 (Near Dam)		
8/26/97	1345	8	<0.4	<0.4	19,000
8/26/97	1345	1	0.58		
7/7/98	0930	8	0.1		
			Site 2 (Mid-Lake)		
8/26/97	1415	8	<1		12,000
7/7/98	1000	4	0.18		
			Site 2.5 (Between 2 and 3)		
8/26/97	1515	8	0.35		
7/7/98	1030	4	0.28		
7/7/98	1035	8	0.49		
			Site 3 (Upper End)		
8/26/97	1452	1	<1		59,000
			Site 4 (Far Upper End)		
7/7/98	1050	4	0.25		

4.2.3 Fish. Raw data for all Truscott Lake fish analyses are contained in Appendix B. Included are sampling date, sample identification number, species, location (see section 3.2.4), total length (mm), wet weight (g), sex (if determined), percent moisture, and wholebody total selenium concentration (mg/Kg dry weight). Data summaries and presentation of statistical analyses are presented in this section.

Wholebody total selenium concentration in all fish collected at Truscott Brine Lake during both 1997 and 1998 (n = 59) ranged from 0.61 to 3.30 mg/Kg dry weight. Overall mean and median total selenium concentrations for all fish were 2.18 and 2.10 mg/Kg respectively. By species, mean and median Se concentrations were 2.07 and 2.00 mg/Kg, respectively for plains killifish and 2.24 and 2.20 mg/Kg, respectively for Red River pupfish (Figure 4.2.3-1). For all fish collected during both years, median selenium concentrations between species were not significantly different (Mann-Whitney p = 0.118) though greater variability in concentrations were observed in Red River pupfish. When analyzed collectively, Se concentrations in all fish conformed to an approximate normal distribution (Anderson-Darling p = 0.236).

For both fish species combined, Se concentrations were slightly higher in 1998 relative to those measured in 1997 (Figure 4.2.3-2). Median concentrations in 1997 and 1998 were 2.00 and 2.25 mg/Kg, respectively, and were found to be significantly different (p = 0.038). Variability among individuals was similar for both years. When analyzed by species, statistical differences in Se concentrations between years was observed for Red river pupfish (p = 0.019)(Figure 4.2.3-3) but not for plains killifish (p = 0.526)(Figure 4.2.3-4).

Slight differences in fish Se concentrations were noted among Truscott Lake fish sampling sites (see section 3.2.4 for sampling locations). Variability among sites was evaluated for combined species (Figure 4.2.3-5) as well as separately for pupfish (Figure 4.2.3-6) and plains killifish (Figure 4.2.3-7). In all cases, Se concentrations in fish from the upper end of the impoundment (Site 3) were not significantly different than those in fish near Truscott Dam (Site 1). However, in all cases, concentrations were significantly different in fish from the upper end of the lake and those collected along the west shore near mid-lake (Site 2) (Figures 4.2.3-5 through 4.2.3-7).

Plains killifish from Truscott Brine Lake were differentiated according to sex (see section 3.4.4) prior to submission for Se analyses. Total selenium concentrations were not significantly different between sexes but levels among females exhibited considerably more variability than those for males (Figure 4.2.3-8). No attempt was made to differentiate between sexes for Red River pupfish.

Spearman's rank correlation analyses were conducted in an attempt to evaluate influence of fish size, as measured by total length and wet weight, on selenium concentration in Truscott Lake fish. When both fish species from the two sampling years were analyzed collectively, a relatively weak (though statistically significant) inverse correlation was observed between Se concentration and total length ($r = -0.288$, $p = 0.027$) and wet weight ($r = -0.322$, $p = 0.013$). When analyzed by species, correlation with total length was stronger, though not statistically significant at $\alpha = 0.05$, for plains killifish ($r = -0.412$, $p = 0.080$) than it was for Red River pupfish ($r = -0.105$, $p = 0.519$). Correlation between total Se and wet weight was not significant for either species though that for Red River pupfish ($r = -0.296$, $p = 0.064$) was closer to being significant than that for the plains killifish ($r = -0.381$, $p = 0.107$). For purposes of further evaluation, fish lengths were compared for the two sampling years. Fish lengths were significantly higher in 1998 than 1997 for plains killifish (Mann-Whitney $p = 0.035$) but not Red River pupfish (Mann-Whitney $p = 0.070$).

Percent moisture data were summarized for Truscott Lake fish to facilitate conversion of dry to wet weight Se concentrations, if desired. Both mean and median values were approximately 75-percent for both species of fish. Percent moisture data for individual fish samples can be found in Appendix B.

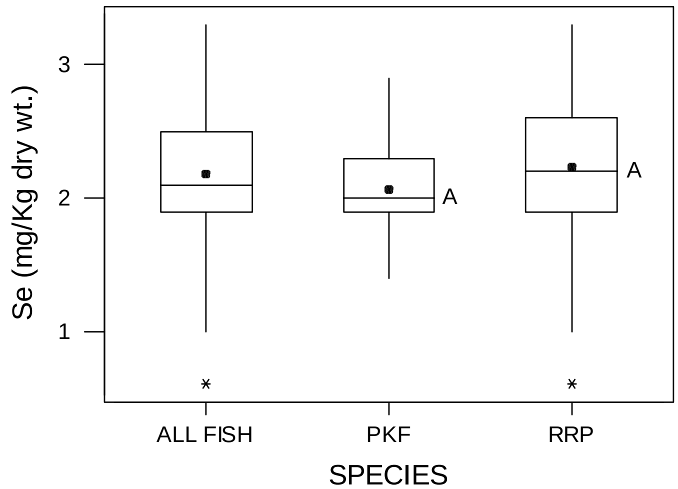


Figure 4.2.3-1
Wholebody fish selenium concentrations, 1997 and 1998, Truscott Lake, TX.
(PKF = plains killifish, RRP = red river pupfish, ALL FISH = combined species)

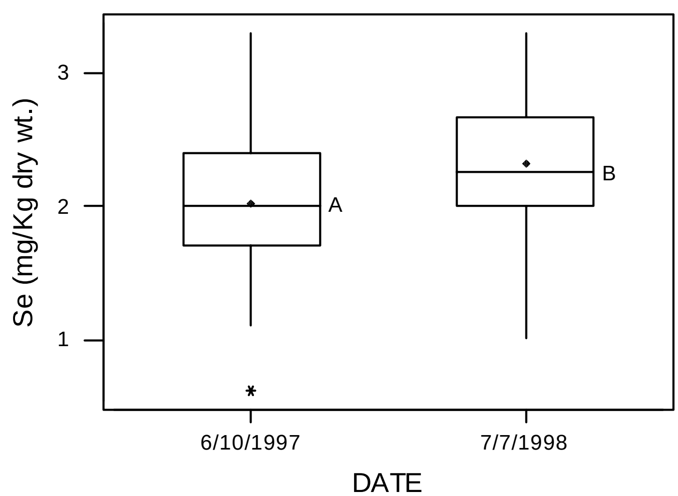


Figure 4.2.3-2
Wholebody fish selenium (Se) concentrations by year for all fish, Truscott Lake, TX.

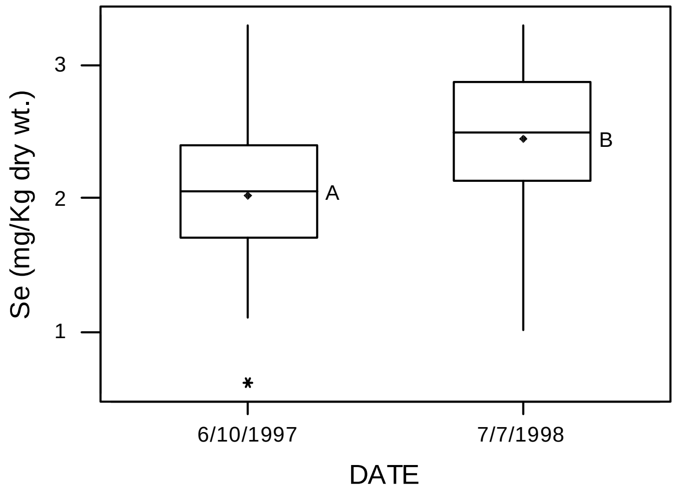


Figure 4.2.3-3.
Wholebody fish selenium concentrations in Red River pupfish by year, Truscott Lake, TX.

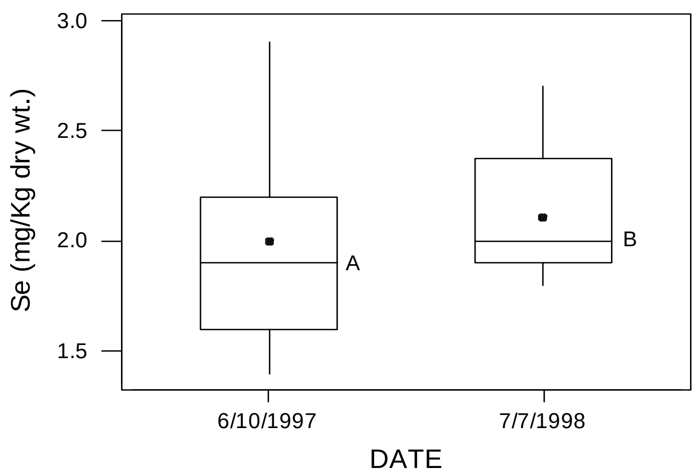


Figure 4.2.3-4.
Wholebody fish selenium concentrations in plains killifish by year, Truscott Lake, Texas.

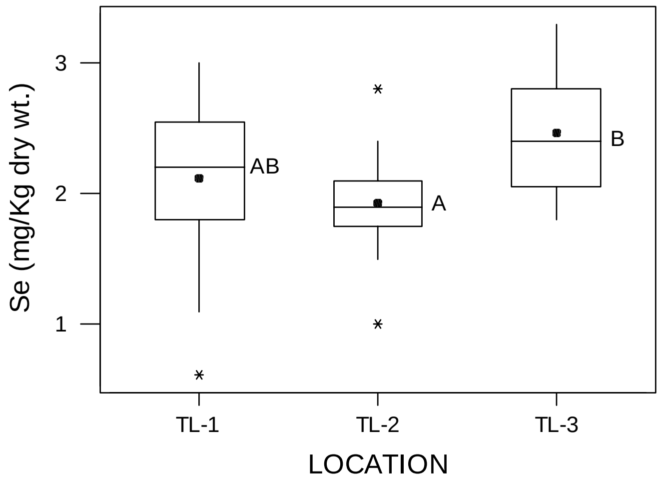


Figure 4.2.3-5.
Wholebody fish selenium concentrations in all fish by sampling location, 1997 and 1998, Truscott Lake, TX.

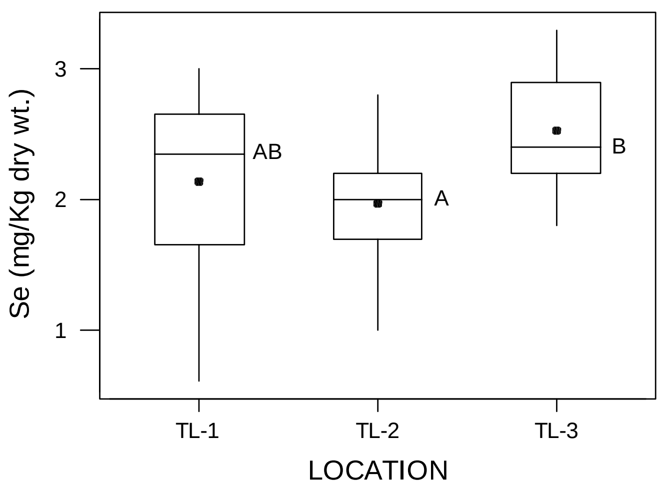


Figure 4.2.3-6.
Wholebody fish selenium concentrations in Red River pupfish by sampling location, 1997 and 1998, Truscott Lake, TX.

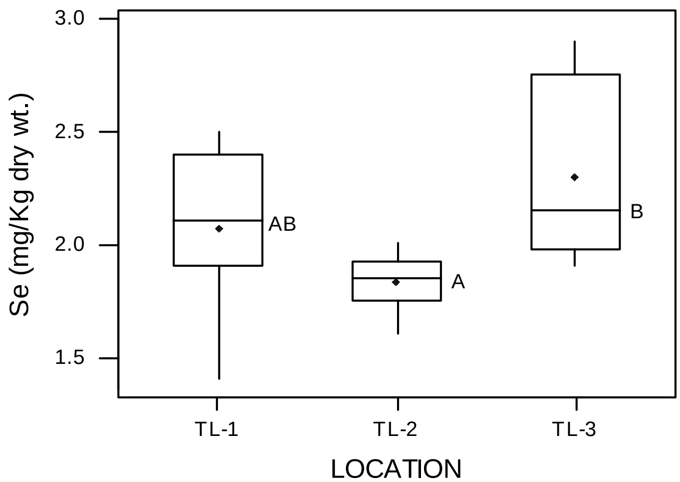


Figure 4.2.3-7.
Wholebody fish selenium concentrations in plains killifish by sampling location, 1997 and 1998, Truscott Lake, TX.

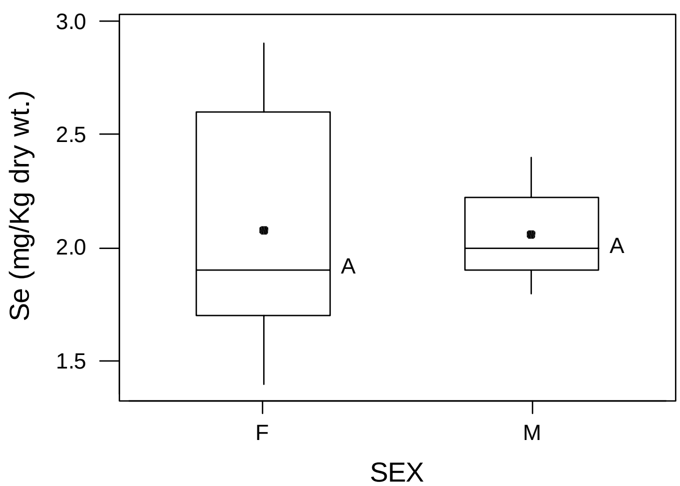


Figure 4.2.3-8.
Wholebody fish selenium concentration in plains killifish by sex, 1997 and 1998, Truscott Lake, TX (F = female, M = male).

4.2.4 Aquatic Vegetation. Limited samples of aquatic vegetation collected in 1998 from the upper end of Truscott Lake included two (2) samples of widgeon grass (*Ruppia* sp.) and one (1) sample of *Chara* sp. Total selenium concentrations in all three samples were less than the sample quantitation limit of 0.4 mg/Kg dry weight.

4.2.5 Bird Use Surveys. Complete results of intensive bird use surveys conducted at Truscott Brine Lake by Texas Tech University researchers are contained in Appendix A. This report should be consulted for complete bird survey study methods, results, and conclusions. In addition, these results are presented in Wrinkle (1999). Summarized major findings and conclusions particularly relevant to selenium monitoring activities include the following:

(a) A total of 113 avian species representing 31 families were observed at Truscott Lake and surrounding project lands over both years of study. Peaks in species richness were observed in April and May.

(b) One Federally- and State-listed bird species, the interior least tern (*Sterna antillarum athalassos*) was observed at Truscott Lake. Least terns were observed feeding but not nesting at the lake.

(c) The lake receives considerable wintertime use by waterfowl (ducks and geese) as well as grebes and American coots.

(d) Surveys and intensive nest searching activities during the breeding season identified very few semi-aquatic bird species nesting at Truscott Brine Lake and nest numbers for these species were few. Semi-aquatic species were limited to the great blue heron (*Ardea herodias*), double-crested cormorant (*Phalacrocorax auritus*), and the red-winged blackbird (*Agelaius phoeniceus*). While the great blue heron and double-crested cormorant are poor model species for selenium exposure owing to their non-sedentary nature and highly mobile feeding behavior, they were the only piscivorous avian species available for egg monitoring. Accordingly, eggs from these species were analyzed for selenium content. Inappropriateness of these species should be considered in Se egg data interpretation. Eggs from the red-winged blackbird, a relatively sedentary insectivore during the breeding season (Hintz and Dyer 1970) were collected and analyzed for Se concentration.

(e) Following egg collection, nests and remaining eggs were monitored throughout the nesting period. Nestlings were carefully examined for characteristic Se-related malformations (e.g. abnormal eye size, twisted feet and legs, missing appendages, deformed bills). No such abnormalities were observed in any nestling, including those from nests where fairly high egg Se (>10 mg/Kg) was reported.

4.2.6 Bird Eggs. Raw data for bird eggs collected at Truscott Brine Lake are included in Appendix B. Included are egg collection date, sample identification number, physical characteristics of eggs (e.g. length, weight), percent moisture, and total selenium concentration (mg/Kg dry wt). These data can also be found in the 1997 – 1998 bird survey report prepared by Texas Tech University (Appendix A). Data summaries and presentation of statistical analyses are presented in this section.

When analyzed collectively, the distribution for Truscott Lake bird egg Se concentration data was highly skewed and exhibited non-normality (Anderson-Darling $p < 0.01$). When analyzed by species, the same pattern was evident for both great blue herons (GBH) and double-crested cormorants (CMT) with p values of <0.01 for each. Concentrations of Se in eggs of red-winged blackbirds (RWBB), however, did not exhibit this level of skewness and conformed to an approximate normal distribution (Anderson-Darling $p > 0.10$).

Selenium concentrations in all bird eggs collected at Truscott Lake during this study ($n = 45$) ranged from 1.9 to 18.0 mg/Kg dry weight with an overall median and arithmetic mean of 3.10 and 4.72 mg/Kg, respectively (Figure 4.2.6-1). The overall geometric mean was 3.90 mg/Kg. Concentrations representing the upper end of the range (three values in the 13 to 18 mg/Kg range) were reported in several eggs collected in 1997 from CMT and GBH. Combined data for both years exhibited greater variability and significantly higher Se concentrations (ranked ANOVA $p = 0.001$) in GBH and CMT eggs relative to those of RWBB (Figure 4.2.6-1). Overall (1997 and 1998) median Se concentrations in eggs of CMT, GBH, and RWBB were 4.7 (range = 2.4 to 18.0), 4.0 (range = 1.9 to 18.0), and 2.8 (range = 2.1 to 3.2) mg/Kg, respectively.

Median bird egg concentrations for combined species were 3.10 and 3.05 for eggs collected at Truscott Lake in 1997 and 1998, respectively. Upper range values (13 to 18 mg/Kg) measured in 1997 in GBH and CMT eggs were not reported in egg samples for these species in 1998 and no values above 9.4 mg/Kg were reported for any species during this second year of study. When analyzed collectively, overall median Se concentrations for all bird eggs were not significantly different between years (Mann-Whitney $p = 0.7491$) (Figure 4.2.6-2).

Egg Se concentrations were compared among avian species for separate years of this study. In 1997, significant differences among species were observed (ranked ANOVA $p < 0.001$). Concentrations in CMT and GBH eggs were statistically similar to one another but significantly greater than those in RWBB eggs (Figure 4.2.6-3). This pattern was not observed in 1998 as median values for all three species were not significantly different (ranked ANOVA $p = 0.195$) (Figure 4.2.6-4). Intra-species comparisons of egg selenium concentrations between sampling years were likewise evaluated. Significant differences in selenium levels were not observed between years for great blue herons (Figure 4.2.6-5), double-crested cormorants (Figure 4.2.6-6) or combined data for both piscivorous species (Figure 4.2.6-7). Similarly, Se concentrations in red-winged blackbird eggs were very similar and not significantly different between 1997 and 1998 (Mann-Whitney $p = 0.961$).

Percent moisture data were summarized for Truscott Lake bird egg samples to facilitate conversion of dry to wet weight Se concentrations, if desired. Both mean and median values were 83-percent for all combined egg samples and were very similar for all species. Percent moisture data for individual egg samples can be found in Appendix B.

Finally, bird egg data collected during this study and presented in this section should be interpreted with consideration given to appropriateness of bird species for Se monitoring and risk evaluation. A considerable amount of literature has been devoted to discussion of the importance of avian behavioral ecology in determining impacts on bird species. These would include Ohlendorf et al. (1986), Lemly and Smith (1987), U.S. Fish and Wildlife Service (1990), Skorupa and Ohlendorf (1991), and Lemly (1995). These issues are likewise discussed in an earlier Tulsa District report (USACE 1993a).

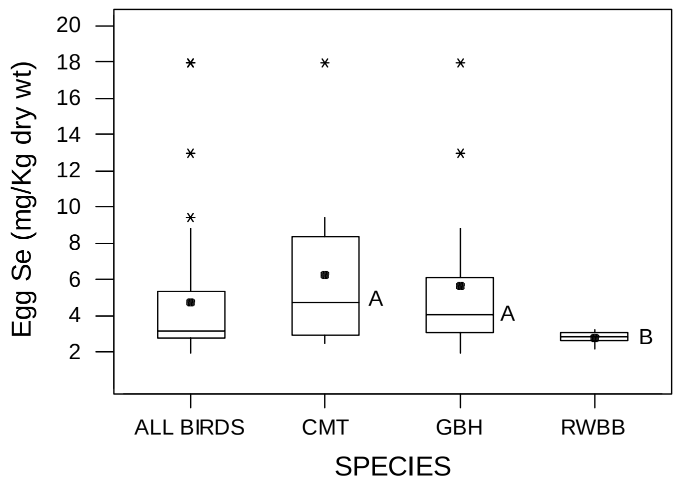


Figure 4.2.6-1.
Selenium concentrations in bird eggs, 1997 and 1998 combined, Truscott Lake, TX.
(CMT = cormorant, GBH = great blue heron, RWBB = red-winged blackbird).

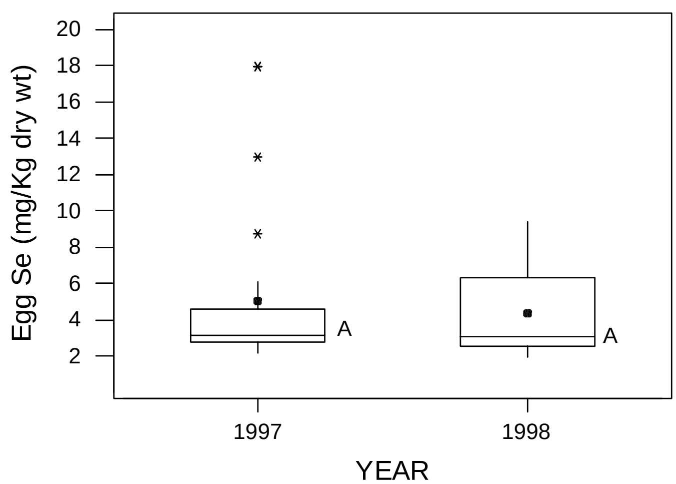


Figure 4.2.6-2.
Selenium concentrations in all bird eggs (combined species) by year,
Truscott Lake, TX.

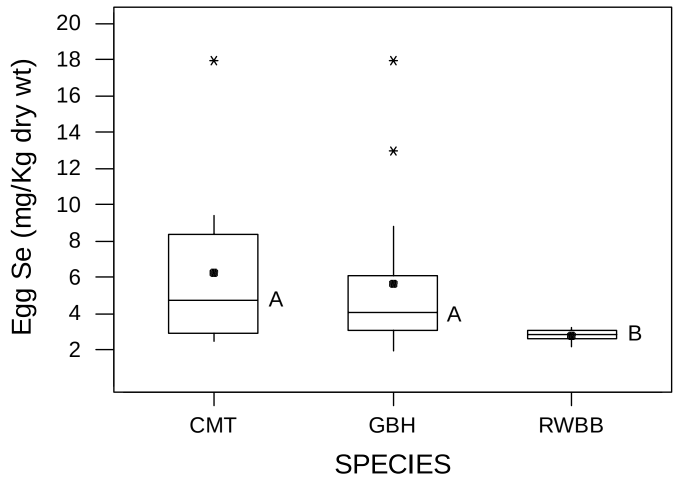


Figure 4.2.6-3.
Selenium concentration in bird eggs collected in 1997, Truscott Lake, TX.

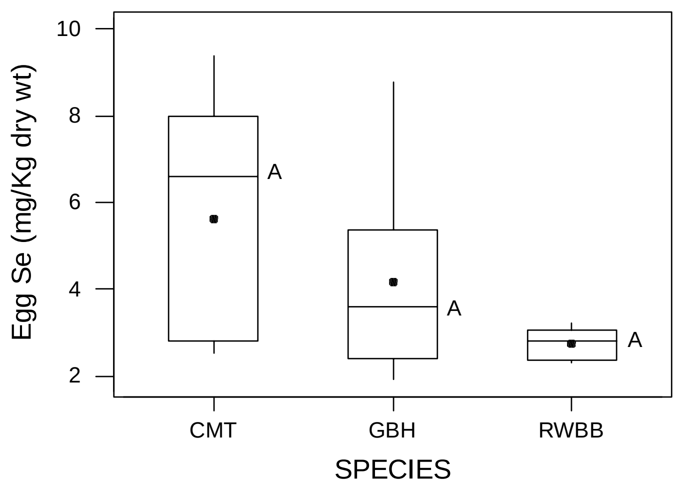


Figure 4.2.6-4.
Selenium concentrations in bird eggs collected in 1998, Truscott Lake, TX.

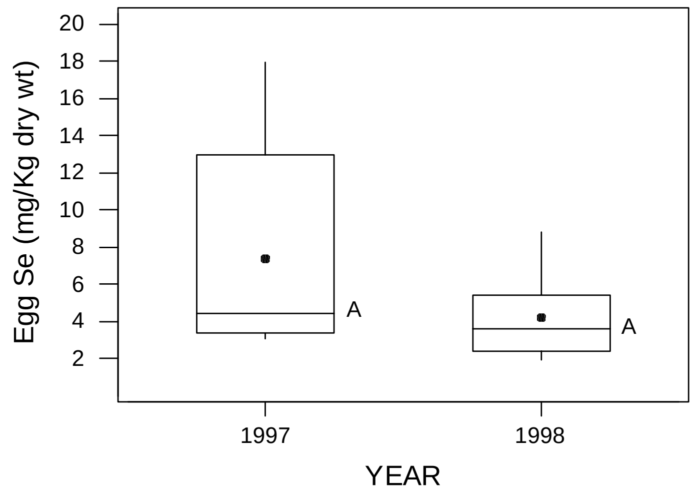


Figure 4.2.6-5.
Selenium concentrations in great blue heron eggs, Truscott Lake, TX.

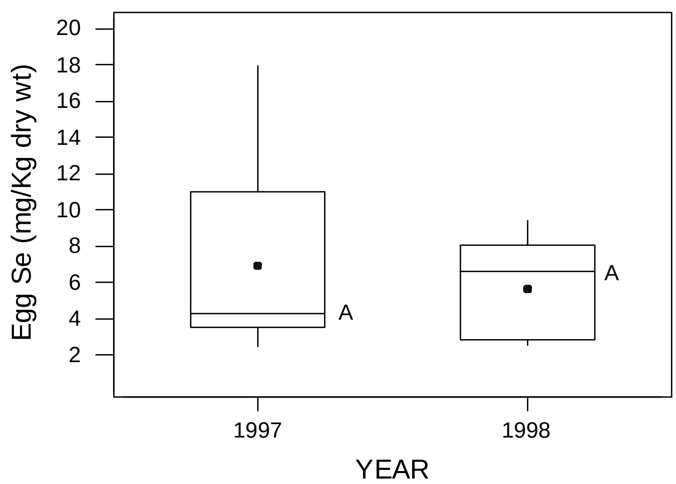


Figure 4.2.6-6.
Selenium concentrations in double-crested cormorant eggs, Truscott Lake, TX.

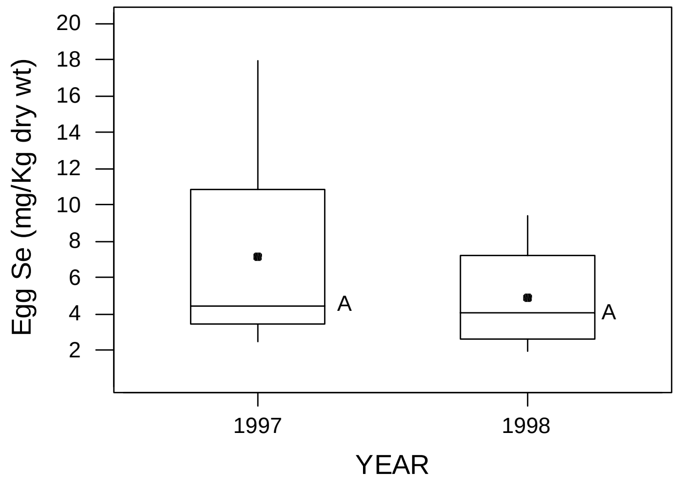


Figure 4.2.6-7.
Selenium concentrations in eggs of piscivorous species (GBH and CMT combined), Truscott Lake, TX.

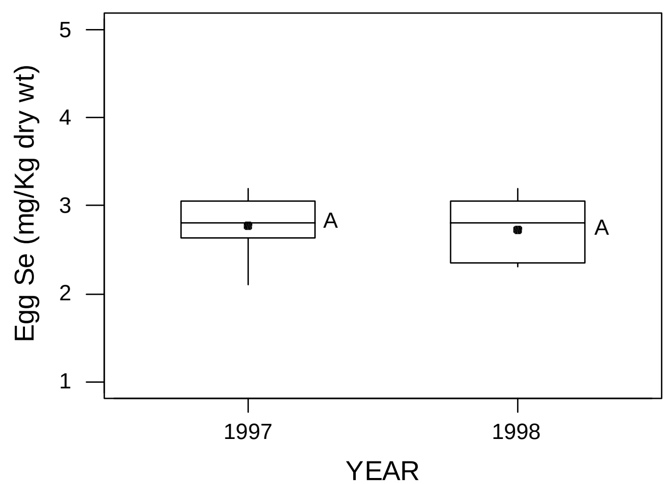


Figure 4.2.6-8.
Selenium concentrations in red-winged blackbird eggs, Truscott Lake, TX.

4.2.7 Bird Livers. Selenium data for individual liver samples collected from female adult red-winged blackbirds at Truscott Lake during July of both 1997 and 1998 are contained in Appendix B. Included are data for sampling date, sample identification number, wet weight (g), percent moisture, and Se concentrations expressed as both dry and wet weight. Data summary and analysis is provided in this section.

Red-winged blackbird liver concentrations in samples collected during both 1997 and 1998 at Truscott Lake ranged from 5.7 to 8.6 mg/Kg dry weight. Median and mean values were 7.45 and 7.24 mg/Kg dry weight, respectively. Median values were slightly higher in 1998 (8.0 mg/Kg) than in 1997 (6.2 mg/Kg) though not statistically different (Mann-Whitney $p = 0.233$) (Figure 4.2.7-1). Average moisture content in bird livers was 69-percent. As bird liver data are frequently reported in the literature on a wet weight basis, these data are likewise included in Appendix B.

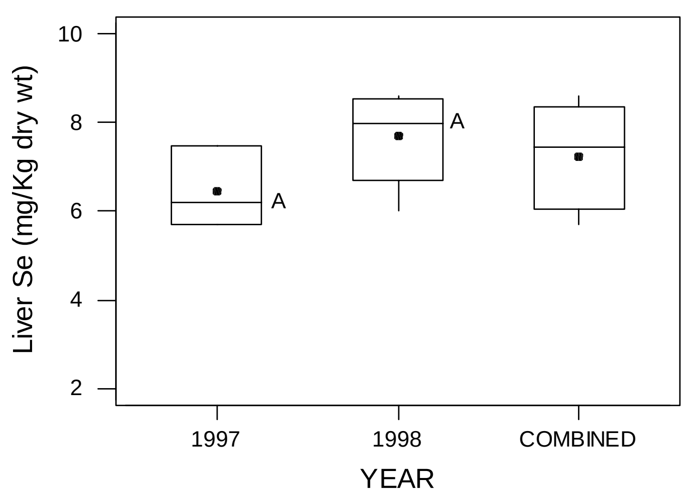


Figure 4.2.7-1.
Selenium concentrations in red-winged blackbird livers, Truscott Lake, TX.

4.2.8 Bird-Ingested Food Items. Three (3) samples of ingested food items were obtained from the esophagus and gizzard of adult female red-winged blackbirds collected at Truscott Lake on 9 July 1997 only. These samples were collected in an attempt to estimate dietary Se exposure to the RWBB as invertebrate samples proved difficult to collect at Truscott Lake. Raw data for these samples are included in Appendix B. Selenium concentrations in these samples ranged from 0.37 to 2.30 mg/Kg dry weight with a mean of 1.09 mg/Kg.

4.2.9 Physicochemical Parameters. While not a direct part of Se monitoring efforts at Truscott Brine Lake, vertical profiles for a variety of physicochemical parameters were collected at Truscott Lake water sampling sites (see section 3.2.1). These measurements were collected in an effort to define limnological characteristics of the lake at the time of sampling. Many of these parameters impact biotic assemblages in aquatic systems and also influence Se cycling in the impoundment. A review of how thermal and oxygen stratification in Truscott Lake could potentially affect Se dynamics is provided in USACE (1993a).

Data collected during this study as well as previous investigations (USACE 1993a) have demonstrated that Truscott Lake exhibits strong thermal stratification in deep water areas during summer months. Anoxia generally occurs at a depth of approximately 9 to 10 m during this time. Conditions measured on 26 August 1997 (Figure 4.2.9-1) are typical of this pattern. A number of similar vertical profiles for various areas of the lake are available in USACE (1993a). These conditions extend to approximately mid-lake where shallow water conditions and mixing owing to extreme wind exposure result in vertical mixing of water strata. During fall, winter, and early spring, the lake currently remains relatively isothermal at all areas though permanent meromixis is a future possibility as dissolved solids increase in the lake. During the period of Se monitoring for this study, specific conductance values were in the 33,000 to 36,000 µS/cm range with little horizontal variability across the lake. Total dissolved solids were in the general range of 20 to 25 g/l.

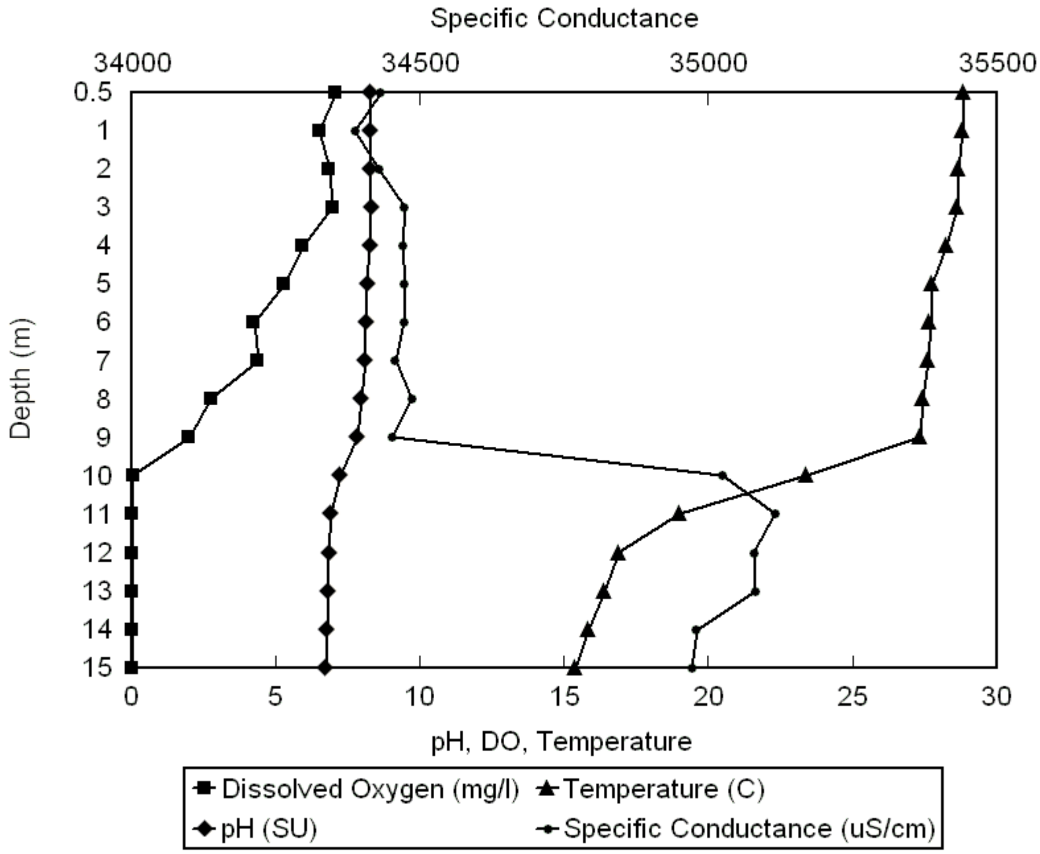


Figure 4.2.9-1.
Vertical profiles of water quality parameters on 26 August 1997, Site 1 (near dam), Truscott Lake, TX.

4.3 Freshwater Ponds. Results of monitoring data collected at freshwater ponds located approximately 0.5 miles (800 m) west of the upper end of Truscott Lake are presented in this section. These ponds are hydraulically distinct from Truscott Lake and are therefore not influenced by brine inflows. Accordingly, these ponds were sampled as general reference or "control" areas when appropriate environmental media were available. Details are provided separately for limited water samples, bird eggs, bird livers, and bird-ingested food items.

4.3.1 Water. Surface (0.5 m depth) water samples for total Se analyses were collected from freshwater ponds on 26 March, 22 April, and 11 June 1997. Total Se concentrations in all samples were below the sample quantitation limit of 1 ug/l. As these concentrations were not expected to drastically change, no additional water samples were collected from these ponds. While not a part of either Truscott Lake or the freshwater ponds, water samples were initially collected from two diked areas on Bluff Creek above Truscott Lake (see Section 3.2.1). Total selenium concentrations in all samples from these areas were 1 ug/l. Dikes in these areas were washed out by high flows during the spring of 1997. These areas were not rebuilt and were consequently abandoned as sampling sites for the remainder of the study.

4.3.2 Bird Use Surveys. Bird use surveys similar to those conducted at Truscott Brine Lake were conducted at the freshwater ponds. Complete results of these surveys and comparisons with findings at Truscott Lake are contained in Appendix A. Most notably, the only nesting semi-aquatic species observed at the freshwater ponds was the red-winged blackbird. Accordingly, monitoring of avian tissues was limited to this species.

4.3.3 Bird Eggs. Raw data for RWBB eggs collected at the freshwater ponds are included in Appendix B. Data summaries and presentation of statistical analyses are presented in this section.

Total Se concentrations in all RWBB eggs collected at the freshwater ponds during both 1997 and 1998 (n = 15) ranged from 2.0 to 3.0 with a nearly identical overall median, arithmetic mean, and geometric mean of 2.60, 2.62, and 2.60 mg/Kg, respectively (Figure 4.3.3-1). Selenium levels were not significantly different in eggs collected in 1997 and 1998 (Figure 4.3.3-1).

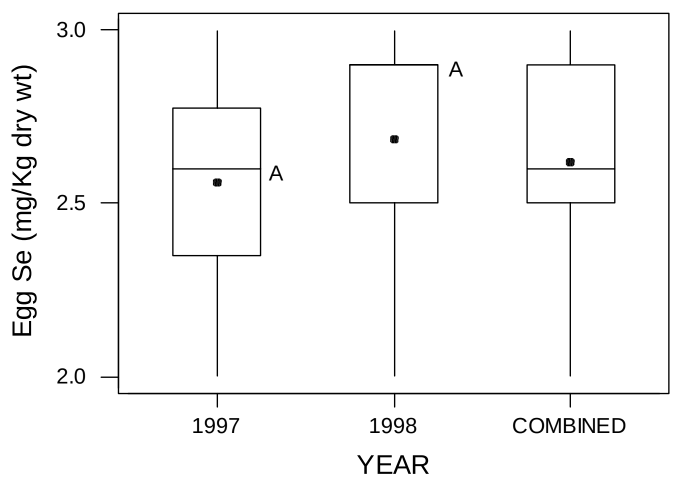


Figure 4.3.3-1.
Selenium concentrations in red-winged blackbird eggs, freshwater ponds.

4.3.4 Bird Livers. Raw data for RWBB livers (n = 10) from freshwater pond areas are contained in Appendix B. For combined study years, liver Se concentrations ranged from 5.6 to 19.0 mg/Kg dry weight with overall median and mean values of 7.85 and 9.67 mg/Kg, respectively. Median hepatic Se concentration was significantly higher in 1997 (9.60) than in 1998 (6.10) (Mann-Whitney $p = 0.037$). Results of all liver analyses for freshwater pond RWBB are shown in Figure 4.3.4-1.

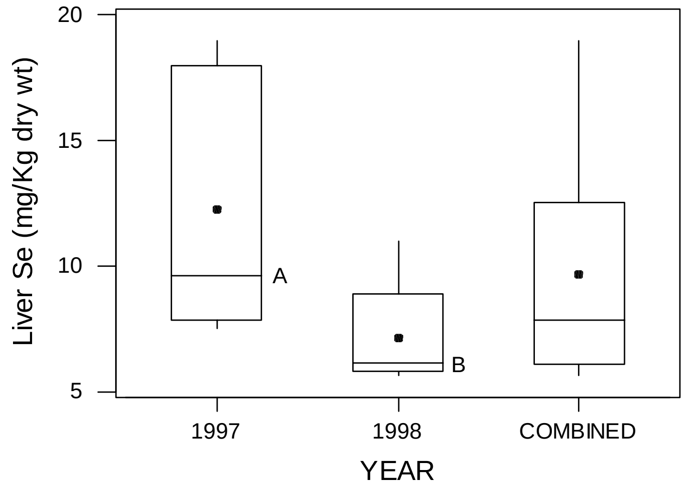


Figure 4.3.4-1.
Selenium concentrations in red-winged blackbird livers, freshwater ponds.

4.3.5 Bird-Ingested Food Items. Five (5) samples of ingested food items were obtained from the esophagus and gizzard of adult female RWBB collected at the freshwater ponds. Raw data for these analyses are included in Appendix B. Selenium concentrations in these samples ranged from 0.39 to 4.2 mg/Kg dry weight with median and mean values of 1.30 and 1.66 mg/Kg, respectively.

4.3.6 Physicochemical Parameters. Surface readings for field water quality parameters (water temperature, pH, specific conductance, dissolved oxygen, total dissolved solids) were measured at freshwater ponds on early spring water sample collection dates in 1997. Specific conductance values in the northernmost pond ranged from 920 to 952 µS/cm while those in the southern pond were higher and ranged from 2,138 to 2,242 µS/cm. Total dissolved solids in the north pond ranged from 0.59 to 0.61 g/l while those in the south pond were in the 1.37 to 1.44 g/l range. Alkaline pH values (8.3 to 8.6) were recorded in both ponds.

4.4 Data Comparisons: Truscott Lake vs. Freshwater Ponds. Data for similar environmental media were compared between Truscott Brine Lake and adjacent freshwater ponds. These media included water, bird eggs, bird livers, and bird-ingested food. Avian data comparisons were possible only for the red-winged blackbird as these were the only semi-aquatic species commonly nesting in both environments. Results of these comparisons are presented in this section.

4.4.1 Water. Comparison of total waterborne Se concentrations between Truscott Lake and nearby freshwater ponds was difficult as levels measured during this study were below analytical quantitation limits (0.5 to 1 ug/l) in both systems. The only conclusion that can be drawn from water data alone is that water column concentrations of total Se in both systems were very low and below that measurable by methods employed by this study.

4.4.2 Bird Eggs. A comparison of total Se concentrations in RWBB eggs collected at Truscott Lake and adjacent freshwater ponds during both years of study is presented in Figure 4.4.2-1. Median concentrations were not significantly different (Mann-Whitney $p = 0.290$) in eggs collected at Truscott Lake and freshwater ponds (medians of 2.8 and 2.6 mg/Kg, respectively). Similar results were obtained when egg data were analyzed separately for 1997 ($p = 0.114$) and 1998 ($p = 0.935$).

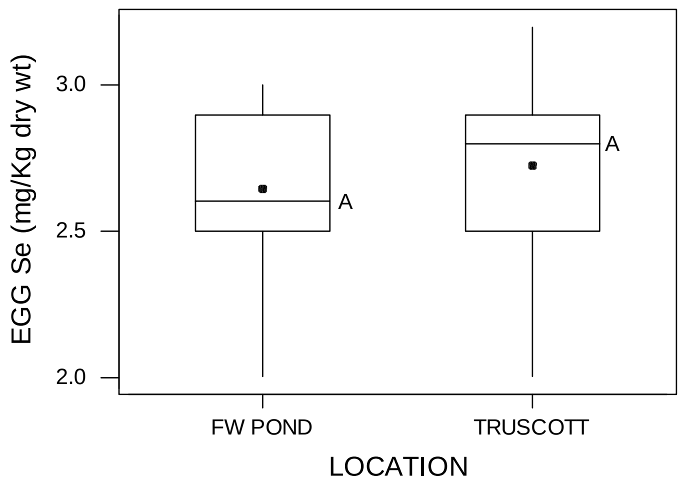


Figure 4.4.2-1.
Comparison of RWBB Egg Se, Truscott Lake and freshwater ponds.

4.4.3 Bird Livers. Overall mean and median Se concentrations in RWBB livers were slightly higher in birds collected at the freshwater ponds relative to those from Truscott Lake though these differences were not statistically significant (Mann-Whitney $p = 0.450$). Hepatic Se concentration was also more variable in birds collected from the freshwater ponds (Figure 4.4.3-1). When analyzed by year, median values were close to being significantly higher in freshwater pond bird livers in 1997 ($p = 0.053$). In 1998, median hepatic Se values from Truscott Lake birds were higher though differences were not significant ($p = 0.347$). Use of bird liver data in Se risk evaluation should always be conducted with caution (see discussion in Section 5.2).

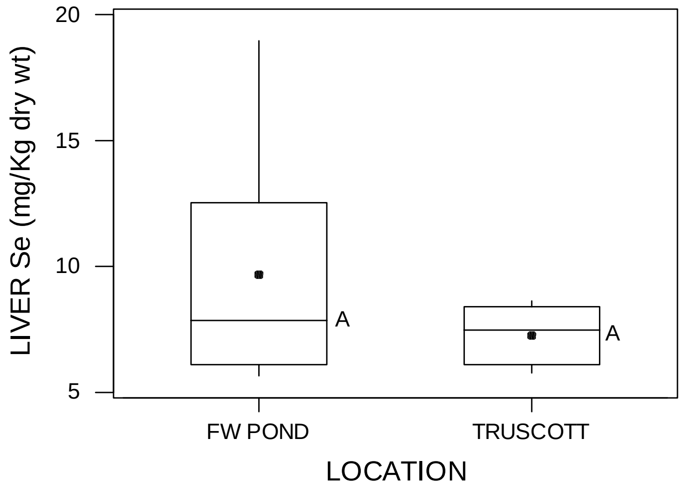


Figure 4.4.3-1.
Comparison of RWBB liver Se, 1997-98, Truscott Lake and freshwater ponds.

4.4.4 Bird-Ingested Food. A comparison of Se concentrations in ingested food items recovered from red-winged blackbirds at Truscott Lake and nearby freshwater ponds is presented in Figure 4.4.4-1. Though sample sizes were small, both variability and Se concentration in these materials was higher in birds from the freshwater ponds. These differences, however, were not statistically significant (Mann-Whitney p = 0.371).

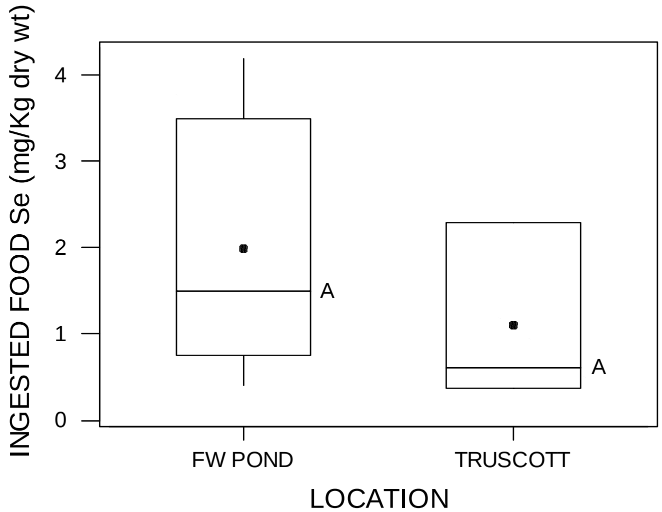


Figure 4.4.4-1.
Comparison of Se concentrations in RWBB-ingested food, 1997, Truscott Lake and freshwater ponds.

4.5 Area VIII (Bateman Pump Station). Results of monitoring activities at the Area VIII (Bateman Pump Station) collection facility are presented in this section. Details are provided separately for water, sediment, fish, and bird census surveys.

4.5.1 Water. Results of total selenium analyses conducted on water samples collected at three locations (see Section 3.4.1) at Area VIII are shown in Table 4.5.1-1. Calculation of summary statistics and statistical comparisons among sites was complicated by a high number of values below sample quantitation limits (0.5 to 1 ug/l). However, concentrations at all three sites on a given sampling date were always similar. On only two of 10 sampling dates were concentrations highest in the pool formed at the collection facility (8-P). In contrast, concentrations were highest upstream of the collection facility (8-U) on four occasions. Levels were identical on three dates. Readings for other water quality parameters are also shown in Table 4.5.1-1.

Table 4.5.1-1. Area VIII (Bateman Pump Station) Selenium and Physicochemical Data, 1997-98.

SOUTH FORK OF WICHITA RIVER APPROX. 0.4 MI UPSTREAM OF WEIR (SITE 8-U)										
	3/25/1997	**4/22/1997**	**6/10/1997**	**7/14/1997**	**8/26/1997**	**12/17/1997**	**1/26/1998**	**4/30/1998**	**7/6/1998**	**9/2/1998**
Total Se (ug/l)	2	<1	4	<1	1	1	2	1	<1	0.9
Water temperature (C)	18.04	21.62	25.35	32.47	27.74			19.83	30.72	27.82
Dissolved Oxygen (mg/l)	9.57	9.03	10.63		10.50				7.59	8.07
Sp. Conductance (uS/cm)	36,464	34,835	22,657	19,120	34,960			38,400	44,497	45,057
pH	7.84	7.77	7.81	8.01	7.76				7.64	7.18
TDS (g/l)	23.3	22.3	14.4	12.3	22.3			24.4	28.4	28.8
SOUTH FORK OF WICHITA RIVER (AREA VIII) AT BATEMAN PUMP STATION POOL (SITE 8-P)										
	3/25/1997	**4/22/1997**	**6/10/1997**	**7/14/1997**	**8/26/1997**	**12/17/1997**	**1/26/1998**	**4/30/1998**	**7/6/1998**	**9/2/1998**
Total Se (ug/l)	1	1	4	<1	<1	2	<1	1	<1	<0.5
Water temperature (C)	19.03	25.01	26.56	31.36	29.39	8.87		18.64	32.0	28.65
Dissolved Oxygen (mg/l)	10.14	10.99	13.36	12.97	10.88	5.46			10.32	10.53
Sp. Conductance (uS/cm)	36,413	34,220	22,674	18,834	34,335	36,800		38,600	43,900	44,911
pH	7.92	7.91	8.03	7.82	7.86	8.95			7.84	7.41
TDS (g/l)	23.3	21.9	14.6	12.0	22.1	23.3		24.6	28.3	28.8
SOUTH FORK OF WICHITA RIVER APPROXIMATELY 75 YDS DOWNSTREAM OF WEIR (SITE 8-D)										
	3/25/1997	**4/22/1997**	**6/10/1997**	**7/14/1997**	**8/26/1997**	**12/17/1997**	**1/26/1998**	**4/30/1998**	**7/6/1998**	**9/2/1998**
Total Se (ug/l)	1	<1	4	<1	<1	<1	1	<1	<1	<0.5
Water temperature (C)	18.42	23.93	26.57	32.08	24.00			18.84	32.31	29.24
Dissolved Oxygen (mg/l)	7.83	12.8	7.92	9.10	13.12				10.90	7.52
Sp. Conductance (uS/cm)	36,300	33,073	20,112	18,100	34,640			33,600	37,500	42,026
pH	7.91	7.63	8.00	7.79	7.30				7.38	7.33
TDS (g/l)	23.2	21.2	12.9	11.5	22.2			21	24.1	26.9

While not a direct part of this study, both total and dissolved Se analyses were conducted during the study period by the USGS on an approximate monthly basis at the Bateman Pump Station. These data are summarized in USACE (2000). Concentrations were comparable to those measured during this study.

4.5.2 Sediments. Limited sediment samples were collected at the three Area VIII sampling sites. On 26 August 1997, total Se concentration in a sediment sample collected from the pump station pool (Site 8-P) was <0.4 mg/Kg dry weight. On 6 July 1998, concentrations were 0.58, 0.36, and 0.18 mg/Kg dry weight at locations upstream of the collection pool (8-U), in the collection pool (8-P), and downstream of the collection pool (8-D), respectively.

4.5.3 Fish. Raw data for all Area VIII fish analyses are contained in Appendix B. Included are sampling date, sample identification number, species, location (see Section 3.4.1), total length, wet weight, sex (plains killifish only), percent moisture, and total Se (mg/Kg dry weight). Data summaries and presentation of statistical analyses are presented in this section.

Wholebody total selenium concentrations in all fish collected at Area VIII sites during both 1997 and 1998 ($n = 100$) ranged from 2.1 to 7.6 mg/Kg dry weight. Overall median and mean levels were 3.80 and 4.06 mg/Kg, respectively. By species, median and mean Se concentrations were 4.45 and 4.49 mg/Kg, respectively for Red River pupfish and 3.10 and 3.42 mg/Kg, respectively for plains killifish (Figure 4.5.3-1). Accordingly, concentrations were found to be significantly higher (Mann-Whitney $p = 0.004$) and more variable in red river pupfish. Caution should be exercised in interpreting these findings as plains killifish were collected at only two of the three sites. When analyzed collectively, all fish Se concentrations deviated from a normal distribution (Anderson-Darling $p = 0.004$). A similar pattern was observed for plains killifish Se concentrations ($p = 0.003$) but concentrations in Red River pupfish alone approximated a normal distribution ($p = 0.519$).

For both fish species at all sites combined, median Se concentrations were nearly identical in fish collected in 1997 and 1998. Median concentrations in 1997 and 1998 were 4.0 and 3.8 mg/Kg, respectively, and were not statistically different ($p = 0.896$) though variability was somewhat higher in 1997 (Figure 4.5.3-2).

Selenium concentrations and variability in fish among the three Area VIII sampling sites were initially evaluated for combined species and years (Figure 4.5.3-3). Median concentrations were nearly identical (4.7 and 4.6 mg/Kg) in fish from upstream of the collection facilities and in the collection area pool. Concentrations were significantly lower (ranked ANOVA $p = <0.001$) at the downstream sampling location (median = 3.0 mg/Kg). When Se concentrations in combined fish species were analyzed for 1997 only, concentrations were significantly higher ($p < 0.001$) in fish upstream of the collection facility relative to those from the brine pool and the downstream location (Figure 4.5.3-4). When 1997 data were analyzed by species, concentrations in Red River pupfish were found to be statistically similar in the collection pool and upstream location. Furthermore, wholebody fish Se concentrations in pupfish in the pool and at the downstream location were not significantly different from one another although those at 8-D and 8-U were statistically distinct ($p = 0.034$) (Figure 4.5.3-5). For plains killifish, median concentrations in 1997 were not different at pool and downstream locations ($p = 0.635$) (Figure 4.5.3-6).

For 1998 data for combined fish species, wholebody median Se concentrations were statistically similar at pool and upstream sampling locations but significantly lower downstream of the collection facility (Figure 4.5.3-7). Similar results were obtained for Red River pupfish only (Figure 4.5.3-8). For plains killifish, concentrations were significantly higher in the brine collection pool than they were downstream of the weir (Figure 4.5.3-9). When plains killifish results from combined sampling sites were analyzed by sex, no significant differences in Se content were noted though greater variability was observed among female fish (Figure 4.5.3-10). Similar comparative results were observed in plains killifish collected from Truscott Lake (Section 4.2.3).

Spearman's rank correlation analyses were conducted in an attempt to evaluate influence of fish size, as measured by total length and wet weight, on Se concentrations in Area VIII fish. When both species from all sites for the two sampling years were analyzed collectively, a significant inverse correlation was observed between Se concentration and total length ($r = -0.441$, $p = <0.001$) and wet weight ($r = -217$, $p = 0.030$). When analyzed by species for both sampling years, an inverse correlation between Se level and total length was fairly strong and significant at $\alpha = 0.05$ for plains killifish ($r = - 0.536$, $p <0.001$). Interestingly, no significant relationship was observed between Se level and total length for Red River pupfish ($r = -0.055$, $p = 0.674$). Similar results were obtained for correlation between Se concentration and wet weight. For plains killifish, a significant inverse relationship was observed ($r = -0.492$, $p = 0.001$). The relationship was positive, weak, and not statistically significant for pupfish ($r = 0.098$, $p = 0.459$). When analyzed by species, differences in total lengths between sampling years (1997 vs. 1998) were not significantly different with the exception of 1998 plains killifish lengths. For this year, total lengths of fish collected downstream of the Bateman Pump Station were significantly greater than those of fish collected from the pool. This may have at least partially accounted for differences in total Se concentrations in killifish at these two locations in 1998 (Figure 4.5.3-9).

Percent moisture data were summarized for Area VIII fish to facilitate conversion of dry to wet weight Se concentrations, if desired. Both mean and median values were 74-percent for combined fish species. By species, average moisture content was 73- and 75-percent for Red River pupfish and plains killifish, respectively. Percent moisture data for individual fish samples can be found in Appendix B.

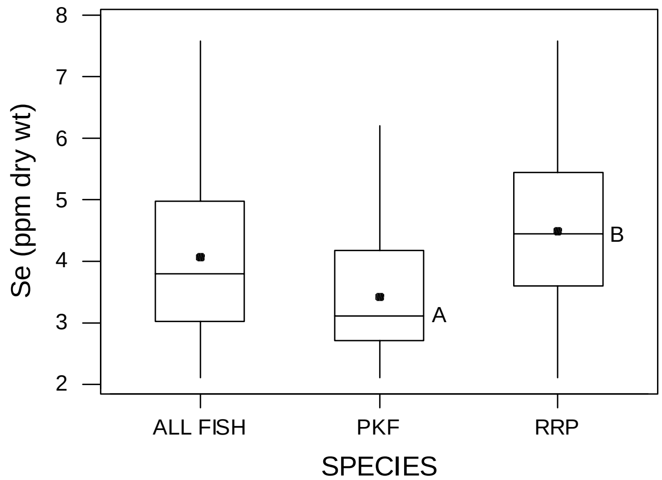


Figure 4.5.3-1.
Selenium concentrations in fish combined from all Area VIII sites, 1997 and 1998.

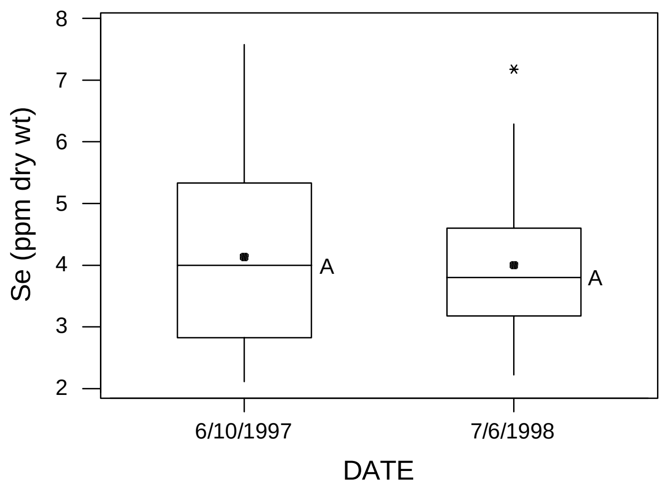


Figure 4.5.3-2.
Selenium concentrations by date in fish combined from all Area VIII sites.

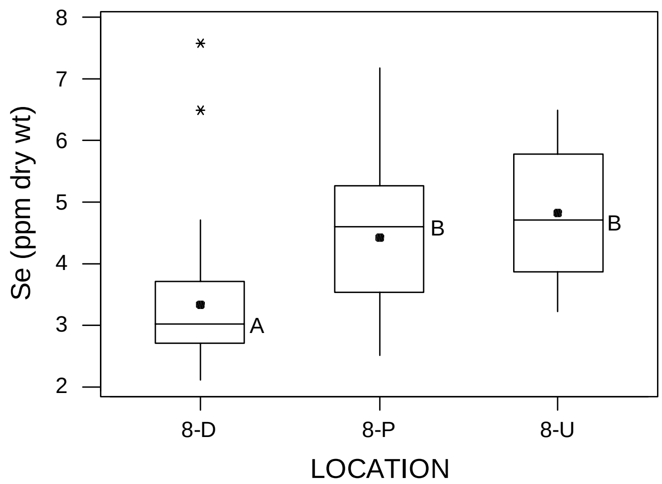


Figure 4.5.3-3.
Selenium concentrations in all fish by Area VIII sites, 1997 and 1998.

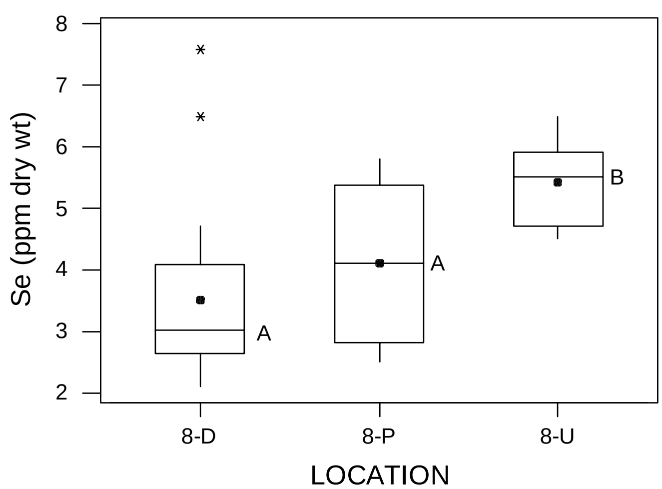


Figure 4.5.3-4.
Selenium concentrations in all Area VIII fish by site, 1997.

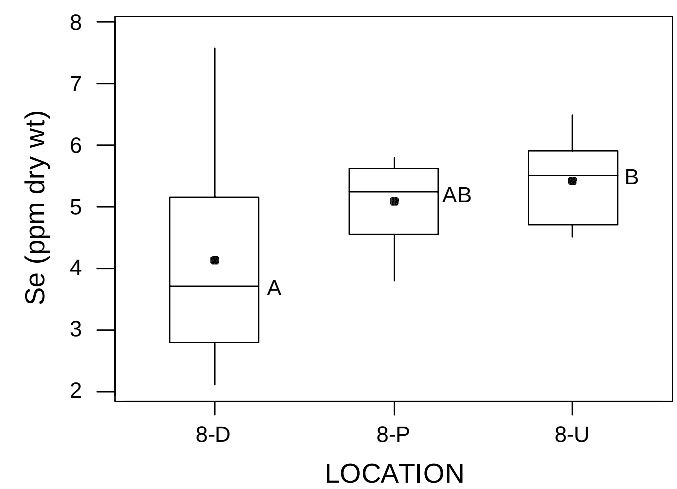


Figure 4.5.3-5.
Selenium concentrations in Red River pupfish by Area VIII site, 1997.

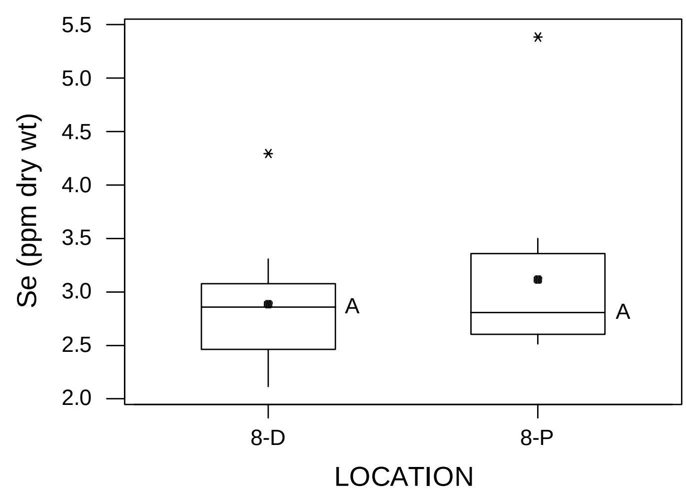


Figure 4.5.3-6.
Selenium concentrations in plains killifish by Area VIII site, 1997.

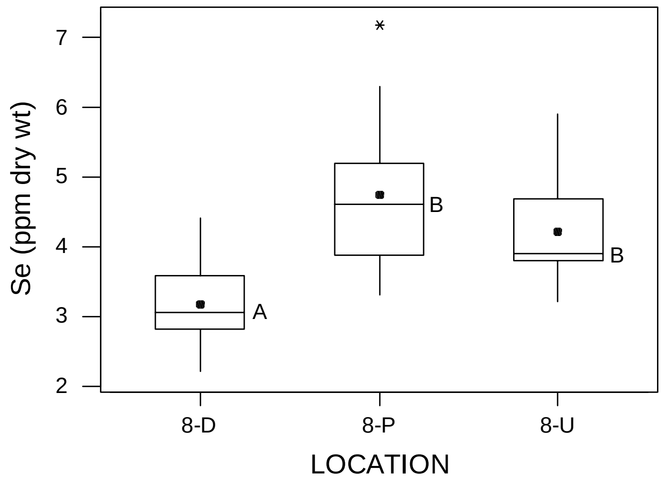


Figure 4.5.3-7.
Selenium concentrations in all Area VIII fish by site, 1998.

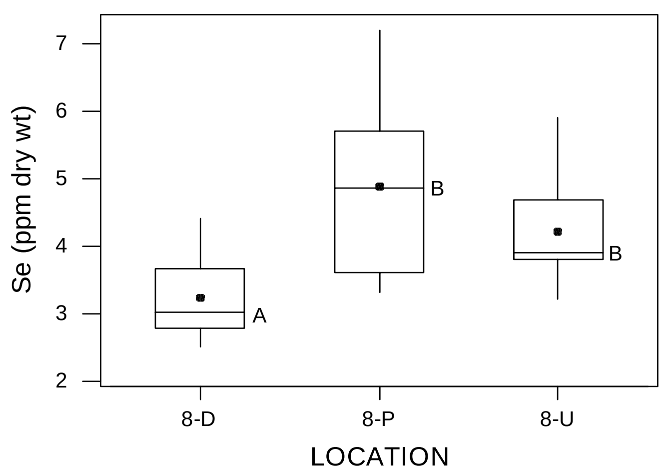


Figure 4.5.3-8.
Selenium concentrations in Red River pupfish, Area VIII sites, 1998.

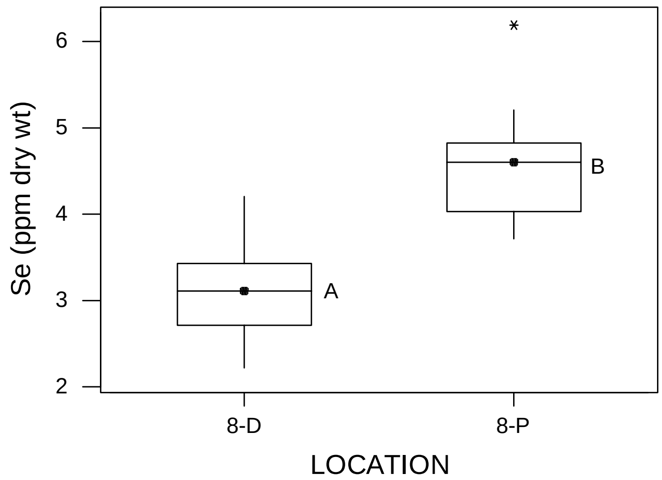


Figure 4.5.3-9.
Selenium concentrations in plains killifish, Area VIII sites, 1998.

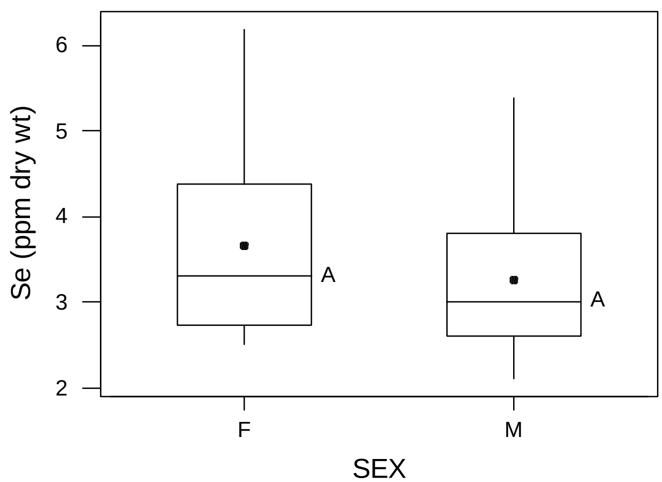


Figure 4.5.3-10.
Selenium concentrations by sex, plains killifish combined from all Area VII sites, 1997 and 1998.

4.5.4 Bird Use Surveys. Complete results of intensive bird use surveys conducted at Area VIII by Texas Tech University researchers are contained in Appendix A. This report should be consulted for complete study methods, results, and conclusions. Summarized major findings and conclusions particularly relevant to Se monitoring activities include the following:

(a) For combined years, a total of 36 avian species representing 17 families were observed at Area VIII facilities and the surrounding area. Species richness peaked in May and June with the number of species ranging from 7 to 13. In 1997, the most abundant species included the mourning dove, Bewick's wren, scissor-tailed flycatcher, northern mockingbird, and ash-throated flycatcher. In 1998, the five most abundant species were turkey vulture, mourning dove, great-tailed grackle, Bewick's wren, and scissor-tailed flycatcher.

(b) No Federally- or State-listed threatened or endangered bird species were observed.

(c) Surveys and intensive nest-searching by Texas Tech University at Area VIII failed to identify any semi-aquatic bird species nesting in the vicinity of the Bateman Pump Station during either 1997 or 1998. As such nesting birds were absent, it was not possible to collect avian eggs for Se monitoring from appropriate bird species.

4.6 Area X (Lowrance Pump Station). As brine collection facilities at Area X on the Middle Fork of the Wichita River were not fully constructed and operational, only limited data were collected at this location as a part of this study. Results are briefly summarized below.

4.6.1 Water. Total selenium concentrations in water samples collected at Area X on 26 February 1997 and 7 July 1998 were 13 and 14 ug/l, respectively. While not a part of this study, monthly Se analyses during the time period for this study (February 1997 through September 1998) conducted by the USGS at Area X (n = 20) were similar to those obtained for this investigation and ranged from 10 to 16 ug/l with an overall mean of 13 ug/l.

4.6.2 Fish. Total selenium in limited fish samples collected on 7 July 1998 at Area X were considerably higher than those measured at other project locations and reflect higher natural waterborne Se at this site. Wholebody Se levels in all combined fish as well as concentrations segregated by species are shown in Figure 4.6.2-1. For all fish, mean and median concentrations were 24.4 and 26.0 mg/Kg dry weight, respectively. While limited sample sizes precluded rigorous statistical comparisons, Se concentrations varied considerably among fish species. Average concentrations were highest in plains minnows and red shiners, slightly lower in plains killifish, and lowest in Red River pupfish (Figure 4.6.2-1). Raw data for Area X fish analyses are contained in Appendix B.

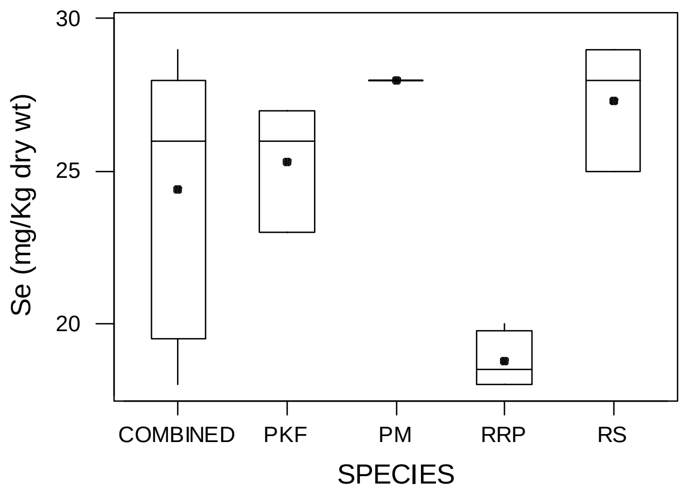


Figure 4.6.2-1.
Wholebody selenium concentrations in fish from Area X.
(Combined = all species, PKF = plains killifish, PM = plains minnow, RRP = Red River pupfish, RS = red shiner).

5.0 COMPARISON OF MONITORING RESULTS WITH CONCERN LEVELS

5.1 General. Results obtained for this monitoring study were compared to both "background" selenium concentrations typical of environmental media from "Se-normal" environments as well as levels of concern for protection of fish and wildlife resources. This comparison was provided in an effort to establish Se-related status of project features after approximately 11 years of project operation. A brief review of levels of concern as well as comparison of monitoring results to these levels is provided in the following sections.

5.2 Background Concentrations and Levels of Concern. Considerable literature exists regarding selenium levels of concern for a variety of environmental media. This literature should be thoroughly reviewed for an overall understanding of the complex issues involved with selenium risk evaluation. A brief review of these issues is provided in this section.

Considerable discussion regarding Se levels of concern related to brine disposal lakes for the original Red River Chloride Control Project is provided in USACE (1993a). As noted in this document, project impoundments such as Truscott Brine Lake are designed solely for disposal of collected brines. As such, primary environmental concerns center around potential impacts on semi-aquatic organisms tied to these systems via food chain dynamics, and not maintenance of diverse communities of exclusively aquatic species (e.g., fish). Owing to a demonstrated sensitivity of aquatic birds to waterborne Se, their potential use of brine disposal lakes, and substantial information regarding impacts on these species, birds were (and continue to be) the focus for Se-related impact evaluation for brine impoundments associated with the project. This focus should be carefully considered in threshold evaluation for Truscott Brine Lake.

For brine collection areas (i.e. Areas VIII, X, and future areas), concerns exist not only for impacts on birds using these facilities, but also for other categories of fish and wildlife inhabiting and using these areas. Accordingly, the literature was reviewed for levels of concern associated with protection of other aquatic species (primarily fish). This is not a significant distinction as levels of concern are similar for birds and other categories of fish and wildlife.

Owing to two distinct categories of Se-related impacts on aquatic birds, it was necessary to distinguish between Se criteria for: (1) potential reproductive impairment of birds nesting at the project areas, and (2) potential detrimental impacts on adult and juvenile birds nesting at sites removed from the project (e.g., wintering waterfowl). In the 1993 evaluation (USACE 1993a), a total waterborne Se concentration of 10 ug/l was used as a threshold value protective of avian embryotoxicity. For impacts on adult and juvenile birds in the absence of reproductive concerns, a threshold value of 34 ug/l was proposed. Finally, a sediment concern threshold level of 4 mg/Kg (dry weight) was used in this evaluation. Literature citations supporting these criteria are provided in USACE (1993) and should be reviewed for an understanding of issues related to threshold estimation for this study.

Subsequent to the USACE (1993a) report, a significant amount of literature has provided additional information on threshold levels for Se in the environment and their application to risk evaluation. Principal among these are Lemly (1993, 1995, 1996), Skorupa et al. (1996), and Heinz (1996). In addition, Se concentrations in a number of environmental matrices from field case studies where Se toxicity has been observed have been reported by Skorupa et al. (1996) and Skorupa (1998). Collectively, these publications have provided additional information for establishment of Se toxicity thresholds in the aquatic environment and have generally resulted in a gradual lowering of concentrations reported to be toxic to fish and wildlife.

One area of apparent consensus among Se researchers is that waterborne Se concentration in and of itself is a poor predictor of impact on fish and wildlife and that water (as well as sediment) data should be evaluated along with Se concentrations in food chain organisms and fish and wildlife tissues for conclusions regarding Se impacts (Lemly 1996). For ultimate assessment of bird-related impacts, avian eggs are believed to be the best biotic matrix for risk/impact assessment though considerable between-species variability in embryo sensitivity exists (Lemly 1993, Skorupa et al. 1996). The same can be said for risk/impact assessment for fish assemblages. Complexities involved with using water-based criteria for impact prediction have even resulted in proposed methods for deriving site-specific water quality criteria for Se (e.g., Van Derveer and Canton 1997, Lemly 1998). Important considerations in deriving site-specific crieria appear to be Se speciation, sediment organic content, and application to lotic versus lentic systems (Van Derveer and Canton 1997). The current USEPA chronic criteria for Se (as well as the State of Texas chronic water quality standard) is 5 ug/l.

Despite the complexities and uncertainties involved, it was still necessary to derive water and sediment criteria for use in evaluation of monitoring results. While further site-specific monitoring of both biotic and abiotic environmental matrices will undoubtedly reduce this uncertainty as the project progresses (and is, in fact, a significant goal of monitoring efforts for the project), literature values were initially chosen for comparison purposes. Given the complexities and uncertainties involved, a range of threshold values appearing in the literature was chosen for comparison to monitoring results.

Though not confined exclusively to impacts on birds, Lemly (1995) assigned a "low hazard" (defined as ". . . periodic or ephemeral toxic threat that could marginally affect the reproductive success of some sensitive species, but most species will be unaffected.") rating to <u>dissolved</u> (0.45 um filtered) Se concentrations of 2 to 3 ug/l based on an extensive literature review. Later, Lemly (1996) recommended that waterborne Se concentrations of 2 ug/l or greater (total recoverable basis in 0.45-um filtered samples) be considered "highly hazardous" to the health and long-term survival of fish and wildlife. Though originally based on dissolved concentrations (totals might be slightly higher) and not confined exclusively to birds, a total Se concentration of 2 ug/l was used as the lower value for the threshold range for this evaluation. Given conservative assumptions associated with this value, this lower end might be considered as "ultraconservative" for purposes of this evaluation. In studies relating Se concentrations in water to bioaccumulation of Se in bird eggs, Skorupa and Ohlendorf (1991) proposed 10 ug/l waterborne Se as protective of avian embryotoxicity under most conditions. This was the concentration used in the 1993 evaluation and was retained as the upper limit of the threshold range for this evaluation. Consequently, a range of 2 to 10 ug/l was used as a minimum threshold total waterborne Se value range for impacts on breeding birds.

The threshold concentration of 34 ug/l total Se for impacts on non-breeding birds was originally based on recommended dietary exposure for non-breeding birds and empirically-derived regression equations for prey accumulation of Se (see USACE 1993a). Nothing could be found in the recent literature to justify modification of this threshold and it was therefore retained for use in interpretation of monitoring results and impact assessment for young and adult non-breeding bird species.

Studies cited in Skorupa et al. (1996) documented lowest observed adverse effect levels (LOAELs) for fish and wildlife via bioaccumulation at total waterborne Se concentrations in the 1.5 to 3 μg/l range. This level was therefore adopted for conservative comparison to monitoring results where direct impacts on fish and other aquatic organisms are of concern (i.e. collection facilities). It is apparent that this concentration range coincides with the lower end of the range employed for breeding birds (as described above).

Currently, there is no well developed empirical basis for assessing fish and wildlife risk as a function of sediment Se concentration (Skorupa et al. 1996, Van Derveer and Canton 1997). Sediment concentrations are particularly important in systems where the benthic detrital food web may influence Se transfer (Van Derveer and Canton 1997). Lemly (1995) characterized sediment Se concentrations of 2-3 mg/Kg dry weight as "low hazard" (an assessment again not entirely based on bird data). Skorupa et al. (1996) cited unpublished data, which suggested egg Se concentrations exceeded embryotoxicity thresholds for sensitive bird species in black-necked stilt eggs at ponds averaging greater than or equal to 1.8 ppm Se in sediments. They also cited studies reporting an approximate background Se concentration of <1.9 mg/Kg in Texas freshwater environments. Based on a review of field data from throughout the United States, Van Derveer and Canton (1997) derived a "predicted effect level" of sediment Se concentrations in the range of 2.5 mg/Kg and an "observed effect level" in the range of 4.0 mg/Kg. They also cited sediment total organic carbon (TOC) concentrations as important considerations in these evaluations. Finally, a 4 mg/Kg concern threshold was proposed by Lemly and Smith (1987) and was the value used in the original Crowell Lake evaluation (USACE 1993a). Accordingly, an approximate minimum threshold range of 2 to 4 mg/Kg dry weight Se in sediments was used in comparison to monitoring results for impacts on both birds and other aquatic organisms. Again, the lower end of the range (around 2 mg/Kg) might be considered "ultraconservative" for purposes of this evaluation.

"The most important aspect of selenium accumulation in aquatic food chains is not direct toxicity to the organisms themselves but, rather, the dietary source of selenium that they provide to fish and wildlife." (Lemly 1996). Accordingly, fish, aquatic vegetation, and recovered bird-ingested food were evaluated as a food source for semi-aquatic birds using Truscott Brine Lake and brine collection facilities. Based on a thorough review of a number of feeding studies and investigations of dietary exposure, Skorupa et al. (1996) cited a range of 2.5 to 8 mg/Kg Se (dry weight) dietary exposure as a reproductive threshold for breeding birds. Similarly, these authors cited a range of 10 – 15 mg/Kg Se (dry weight) as a dietary threshold range for non-breeding birds subject to winter stress. Accordingly, these Se concentrations in potential food items for birds were used as levels of concern for comparison with monitoring results for this study.

For brine collection areas, it was also desirable to evaluate wholebody fish Se concentrations with respect to potential reproductive impacts on fish species themselves. Based on their review of a number of studies, Skorupa et al. (1996) cited 4 – 6 mg/Kg wholebody Se on a dry weight basis as an estimated true threshold range for reproductive impairment in sensitive fish species (e.g. perch, bluegill, salmon). While this threshold range was used for comparison to monitoring results for this study, the conservative nature of this range should be recognized as these sensitive species are not present at brine collection areas in the Wichita River basin.

Considerable literature exists regarding interpretative value of measuring *in ovo* Se concentrations in avian species. A synthesis of these studies, presented in Skorupa et al. (1996), reveals considerable between-species variation in embryo sensitivity to bird egg selenium. Accordingly, a threshold range of 6 – 50 mg/Kg dry weight Se in bird eggs was identified by Skorupa et al. (1996) and is applicable from sensitive to tolerant bird species, respectively. Heinz (1996) recommended that about 3 mg/Kg of Se on a wet-weight basis in bird eggs should be considered the threshold for reproductive impairment. Using average moisture content in eggs from Truscott Lake (83%), this recommendation corresponds to a threshold Se concentration of around 18 mg/Kg on a dry weight basis.

Use of threshold values for selenium concentrations in bird livers should be approached with caution and have a limited basis for interpreting risk (Heinz 1996, Skorupa et al. 1996). Because Se concentrations in hepatic tissue are sometimes very elevated in avian species inhabiting Se-normal environments, elevated levels should only be an indication that further study and evaluation of additional environmental matrices is warranted (Skorupa et al. 1996). Recognizing these uncertainties, Heinz (1996) recommended that concentrations greater than 10 mg/Kg of Se in the liver on a wet-weight basis be considered possibly harmful to the health of young and adult birds and that concentrations in excess of 3 mg/Kg wet weight in livers of laying females be associated with reproductive impairment. Using average moisture content of livers collected during this study (69%), these recommendations correspond to dry weight threshold concentrations of 10 and 32 mg/Kg for reproductive impairment and impacts on young and adult birds, respectively. These threshold values were employed for comparative purposes in this study though uncertainties are recognized for interpretation of bird liver Se data.

"Background" selenium concentrations were defined as those typical for a variety of environmental media in selenium-normal environments. These concentrations, as well as justification for their establishment, were provided by Skorupa et al. (1996). Accordingly, these concentrations were used for comparing Se concentrations obtained during this study to those typical of Se-normal systems.

5.3 Truscott Lake Comparisons. Comparisons of Se concentrations in 1997 – 1998 environmental media from Truscott Lake with both background concentrations and levels of concern to avian species are provided in Table 5.3-1. When compared to typical "background" levels, most media from Truscott Lake were at or below these concentrations during 1997 and 1998. Owing to reported values below analytical quantitation limits, some uncertainty existed as to actual waterborne Se concentrations in the impoundment during the sampling period. However, it is noteworthy that total waterborne Se concentrations remained below detection limits in Truscott Brine Lake following approximately 11 years of project operation. Sediment Se concentrations were likewise low and at the lower end of the background range. Similar results were observed for fish and limited samples of aquatic vegetation. When compared to levels of concern for protection of avian species, 1997 – 1998 concentrations in water, sediment, fish, and aquatic vegetation from Truscott Lake were well below estimated protective levels for both breeding and young and adult non-breeding birds (Table 5.3-1).

Table 5.3-1. Comparison of 1997 – 1998 Truscott Lake selenium monitoring results with "background" values and levels of concern for protection of avian species. All values are mg/Kg dry weight unless otherwise noted.

MEDIUM	TRUSCOTT RANGE	TRUSCOTT MEDIAN	"BACKGROUND" [1]	LEVELS OF CONCERN [2]
Water (μg/l)	<0.5 - <1.0	<0.5 - <1.0	0.1 – 0.4 (typically <0.2)	2 – 10 (breeding birds) 34 (adult, non-breeding birds)
Sediment	<0.4 – 0.58	0.28 [6]	0.2 – 2.0 (typically <1)	2 - 4
Fish [3]	0.61 – 3.30	2.10	<1 – 4 (typically <2)	2.5 – 8 (generally 5) [10] 10 – 15 [11]
Vegetation [3]	<0.4	<0.4	0.1 – 2.0 (typically <1.5)	2.5 – 8 (generally 5) [10] 10 – 15 [11]
Bird Eggs				
Sedentary insectivore	2.1 – 3.2	2.8	< 3 mean <5 max.	6-50 [12] 18 [13] 10 protective of most species
Mobile piscivores [4]	1.9 – 18.0	4.2	< 3 mean <5 max.	10-50 [12] 18 [13] 10 protective of most species
Bird livers [5]	5.7 – 8.6	7.5	8.2 [8] (typically <10)	10 [14] 32 [15]
Bird-ingested food [3]	0.37 – 2.30	1.09 [7]	0.4 – 4.5 [9] (typically <2)	2.5 – 8 (generally 5) [10] 10 – 15 [11]

(1) Typical values in "selenium-normal" environments (Skorupa et al. 1996)
(2) Based on protection of avian species (see text for references)
(3) Evaluated as food source for semi-aquatic birds
(4) Not most appropriate species for Se evaluation. Evaluate with caution.
(5) Limited interpretative value for this medium (see text)
(6) Median of detected values – excludes non-detects
(7) Mean value (n = 3), 1997 only
(8) Insectivore median
(9) Assumes material is 100% aquatic invertebrates
(10) As breeding bird food source -- protection from reproductive effects
(11) As food source -- protection of young and adult non-breeding birds
(12) Represents considerable between-species variation in embryo sensitivity (Skorupa et al. 1996)
(13) Based on Heinz (1996) recommendation of 3 ppm wet weight converted to dry weight using average of 83% moisture in eggs from Truscott
(14) Reproductive impairment – based on 3 ppm wet weight in egg-laying females (Heinz 1996) and 69% moisture content (this study)
(15) Protection of non-breeding young and adult birds – based on 10 ppm wet weight (Heinz 1996) and 69% moisture content (this study)

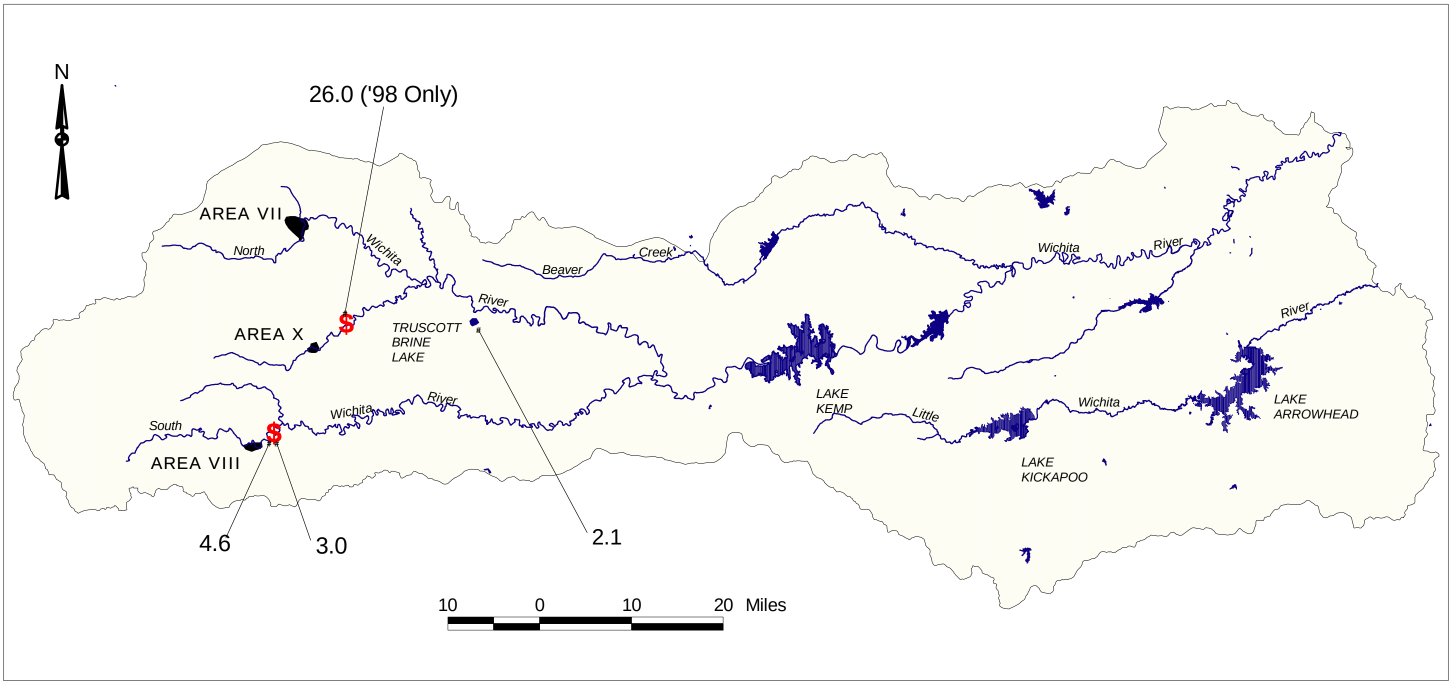
Interesting results were obtained when Se levels in avian tissues from Truscott Brine Lake during 1997 – 1998 were compared to both background and Se levels of concern for protection of avian species (Table 5.3-1). Selenium concentrations in limited samples of bird livers and ingested food items (both for red-winged blackbirds only) were well below both background and levels of concern for protection of bird species. Likewise, Se concentrations in red-winged blackbird eggs for both monitoring years were at approximate background levels and did not approach levels of concern for reproductive effects (Table 5.3-1).

When compared to those for red-winged blackbirds, avian egg monitoring results from Truscott Lake were notably different for great blue herons and cormorants, both of which are highly mobile, piscivorous species. Selenium concentrations in eggs from these species were highly variable, very elevated in some instances, and considerably higher overall than those in red-winged blackbird eggs (see Section 4.2.6). When compared to reported background concentrations, Se levels in eggs from great blue herons and cormorants exceeded both average and maximum background levels (Table 5.3-1). While the median Se concentration in eggs from these species was below levels of concern (even for sensitive bird species), some concentrations in individual eggs equaled or exceeded published levels of concern for reproductive effects (Table 5.3-1).

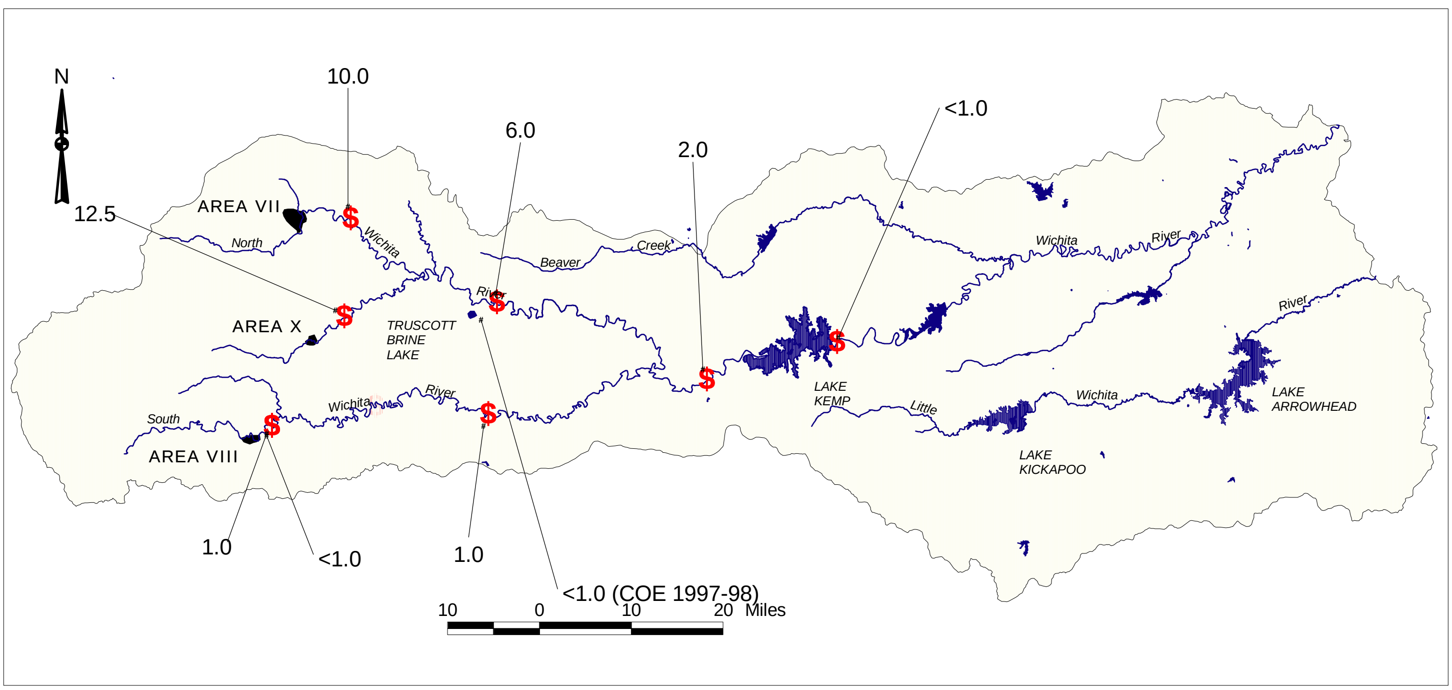
Avian egg monitoring results for selenium-related risk / impact assessment should always be interpreted in light of the appropriateness of selected bird species. A considerable amount of literature has been devoted to discussion of the importance of avian behavioral ecology in determining Se impacts on bird species (e.g., Ohlendorf et al. 1986, Lemly and Smith 1987, U.S. Fish and Wildlife Service 1990, Skorupa and Ohlendorf 1991, Lemly 1995). These studies have concluded that the most appropriate model species for site-specific selenium monitoring are those that are sedentary and therefore closely tied to the environment of interest via food chain dynamics. While cormorants and great blue herons definitely do not meet these requirements, they were the only piscivorous species found nesting at Truscott Brine Lake during both 1997 and 1998 and were therefore selected for egg collection and analysis. Results of monitoring for these species should therefore be interpreted with an understanding that they are not the most appropriate model species for site-specific Se evaluations.

The U.S. Fish and Wildlife Service (1990) stressed the importance of “landscape mosaics” in influencing impacts of contaminants on highly mobile avian species. Impoundments situated within a mosaic of relatively clean aquatic systems (“wet mosaics”) were cited as significantly less dangerous than impoundments in water-limited “dry mosaics”. Accordingly, naturally-occurring Se levels in environmental media from aquatic systems surrounding Truscott Lake were examined and compared to those measured in the lake during the monitoring period for an overall assessment of “mosaic-related” selenium impacts of Truscott Lake on mobile avian species in the project area. While certainly not completely defined, it is apparent that there are a number of aquatic environments in the vicinity of Truscott Lake with documented naturally-occurring waterborne Se levels considerably higher than those at the lake. If highly mobile avian species spent time feeding in these areas, it is probable that they were exposed to prey (fish) much higher in Se than those at the lake. This could have resulted in much higher Se in eggs than if these birds fed on fish exclusively from Truscott Lake and could be a possible explanation for highly variable and elevated Se concentrations in eggs from mobile piscivorous birds measured during this study. While extensive feeding area studies were not a part of this monitoring program, both great blue herons and cormorants were routinely observed feeding both in the lake as well as flying to and from the lake during normal feeding periods.

While Se data for aquatic systems in the vicinity of Truscott Lake are limited, data that do exist for the area are summarized in Figure 5.3-1. As an example, water quality data collected by the USGS during the general time period of this monitoring study (October 1997 to September 1998) on the North Wichita River (which flows north of Truscott Dam) indicate that naturally-occurring total waterborne Se concentrations were in the 9 to 17 µg/l range near Paducah, TX and in the 3 to 11 µg/l range near Truscott Lake (Figure 5.3-1). Similar data collected on the Middle Wichita River (see Section 4.6) indicated total waterborne Se concentration in the 10 to 16 µg/l range with a



Median Total Selenium Concentrations (ppm dry wt.) in Fish (Corps of Engineers 1997-1998)



Median Total Selenium Concentrations (ug/l) in Water, 1996-1997 (from USGS 2000) median Se fish concentration of 26 mg/Kg dry weight – a concentration approximately 13 times higher than the median concentration measured in fish from Truscott Lake. While it is uncertain exactly where mobile bird species were feeding, these data illustrate that there were certainly areas surrounding Truscott Lake where Se levels in water and most likely prey for fish-eating birds far exceeded those measured in the lake during the 1997 to 1998 monitoring period. Interestingly, if mobile fish-eating birds nesting at Truscott Lake fed both in the impoundment and in nearby environments of naturally-occurring high Se, Truscott Lake may have served to reduce Se exposure for these birds. If these trends continue, it is conceivable that Truscott Lake may provide Se-related benefits to avian populations in the area.

It is of interest to note that post-hatch monitoring of avian nestlings for malformations characteristic of Se poisoning was conducted as part of this study (see Appendix A). Despite elevated Se concentrations in some eggs of mobile piscivorous species, no such deformities were noted in any hatchlings during either monitoring year. It should be noted, however, that teratogenic malformations are certainly not the only indication of Se-induced reproductive impacts among birds. In fact, egg hatchability is probably a more sensitive response variable than teratogenesis (Skorupa et al. 1996) though reduced hatching success attributable solely to environmental contaminants is difficult to measure in wild bird populations.

Finally, it should be noted that while results of Se monitoring at Truscott Lake represented conditions present during the monitoring period, a potential for future changing conditions at the lake certainly exists. Results of this monitoring effort should therefore not be implied to represent future conditions. Continued monitoring of Se in a wide range of environmental media at Truscott Lake is certainly justified and will provide further insight into site-specific selenium dynamics and potential impacts on fish and wildlife.

5.4 Area VIII (Bateman Pump Station) Comparisons. Comparisons of Se concentrations measured during 1997 and 1998 in several environmental media at the

Area VIII brine collection facility with both background and levels of concern are provided in Table 5.4-1. Waterborne total Se concentrations were typically similar and above background levels at the three sampling areas at the facility. Waterborne concentrations were generally below the range of concern for impacts on avian species and near the low end of the range of concern for fish and wildlife via bioaccumulation. Se concentrations in limited sediment samples from the facility were both below typical background levels and levels of concern for fish and wildlife (Table 5.4-1).

Table 5.4-1. Comparison of 1997 – 1998 Area VIII selenium monitoring results with "background" values and levels of concern for fish and wildlife. All values are mg/Kg dry weight unless otherwise noted.

MEDIUM	AREA VIII RANGE	AREA VIII MEDIAN [1]	"BACKGROUND" [2]	LEVELS OF CONCERN [3]
Water (µg/l)	<0.5 – 4 (overall) <1 – 4 (upstream) <0.5 – 4 (collection pool) <0.5 – 4 (downstream)	1.5 (upstream) 1.4 (pool) 1.3 (downstream)	0.1 – 0.4 (typically <0.2)	2 – 10 [4] 34 (non-breeding birds) 1.5 – 3 [6]
Sediment	<0.4 – 0.58 (overall) 0.58 (upstream, n=1) <0.4 – 0.36 (pool, n=2) 0.18 (downstream, n=1)		0.2 – 2.0 (typically <1)	2 – 4 [4][5]
Fish	2.1 – 7.6 (overall) 3.2 – 6.5 (upstream) 2.5 – 7.2 (pool) 2.1 – 7.6 (downstream)	3.8 (overall) 4.7 (upstream) 4.6 (pool) 3.0 (downstream)	<1 – 4 (typically <2)	2.5 – 8 (generally 5) [7] 10 – 15 [8] 4 – 6 [9]

(1) Owing to high percentage of censored values, concentrations for water are means calculated by considering censored values = quantitation limits.
(2) Typical values in "selenium-normal" environments (Skorupa et al. 1996)
(3) When appropriate, listed separately for protection of avian species and "fish and wildlife" in general. See text for references.
(4) Protection of breeding birds (see text).
(5) Protection of "fish and wildlife" in general.
(6) Validated LOAEL for fish and wildlife via bioaccumulation. Cited in Skorupa et al. (1996).
(7) As breeding bird food source – protection from reproductive effects.
(8) As bird food source – protection of young and adult non-breeding birds.
(9) Estimated wholebody true threshold range (ca. IC-10) for reproductive impairment in sensitive fish species. Cited in Skorupa et al. (1996).

Median selenium concentrations in Area VIII fish were generally similar upstream of the collection facility and in the brine collection pool, but were somewhat lower downstream of the facility (see Section 4.5.3). Fish data should certainly be evaluated with an understanding that mobility of fish, particularly between the brine collection pool and upstream locations, complicates impact analysis. At all locations, wholebody Se concentrations were at or exceeded the upper end of the reported background concentration range and were over twice the "typical" background value of 2 mg/Kg for fish in Se-normal environments. When evaluated as a food source for fish-eating birds, fish concentrations approached the mid-range of threshold values protective of avian reproductive effects but were lower than threshold values for protection of young and adult non-breeding birds (Table 5.4-1). Wholebody Se concentrations were near the mid-point of the threshold range for reproductive impairment in sensitive fish species, though these threshold values are most likely ultraconservative for fish species present (see discussion in Section 5.2).

Based on monitoring results, it would appear that brine collection activities at Area VIII did not result in substantially increased detrimental Se-related impacts on fish and wildlife during the monitoring period. While somewhat elevated, selenium concentrations in monitored media directly in the brine collection pool were similar to naturally-occurring concentrations measured upstream of the pump station. While mass removal calculations would predict this scenario, monitoring results seem to substantiate these predictions. Conversely, it is possible that Se mass removal as a result of pumping operations may have resulted in reduced downstream impacts as concentrations in media (particularly fish) were lower downstream of the facility. Extensive bird survey results over a two year period failed to identify any semi-aquatic nesting birds at the pump station – an indication that construction of the facility did not provide a significant attractant for breeding birds, at least during the monitoring period.

5.5 Area X (Lowrance Pump Station) Comparisons. Comparisons of limited Area X water and fish Se concentration data with both background and levels of environmental concern are provided in Table 5.5-1. It should be emphasized that at the time of sampling (as well as at date of this report), brine collection facilities at this area had been only partially completed and the pump station was not operational.

Table 5.5-1. Comparison of 1997 – 1998 Area X selenium monitoring results with "background" values and levels of concern for fish and wildlife. All values are mg/Kg dry weight unless otherwise noted.

MEDIUM	AREA X RANGE	AREA X MEDIAN [1]	"BACKGROUND" [2]	LEVELS OF CONCERN [3]
Water (μg/l)	13 – 14 (this study, n = 2) 10 – 16 (USGS, n = 20)	13.5 (this study) USGS mean = 13	0.1 – 0.4 (typically <0.2)	2 – 10 [4] 34 (non-breeding birds) 1.5 – 3 [6]
Fish [5]	18 - 29	26	<1 – 4 (typically <2)	2.5 – 8 (generally 5) [7] 10 – 15 [8] 4 – 6 [9]

(1) Mean value for USGS-collected data.
(2) Typical values in "selenium-normal" environments (Skorupa et al. 1996)
(3) When appropriate, listed separately for protection of avian species and "fish and wildlife" in general. See text for references.
(4) Protection of breeding birds (see text).
(5) Fish data collected in 1998 only
(6) Validated LOAEL for fish and wildlife via bioaccumulation. Cited in Skorupa et al. (1996).
(7) As breeding bird food source – protection from reproductive effects.
(8) As bird food source – protection of young and adult non-breeding birds.
(9) Estimated wholebody true threshold range (ca. IC-10) for reproductive impairment in sensitive fish species. Cited in Skorupa et al. (1996).

Analysis of limited water samples as a result of this study as well as more extensive water quality monitoring at Area X by USGS indicated that waterborne Se concentrations at this location are naturally high and well above typical “background” concentrations. In addition, concentrations exceed threshold values for protection of breeding birds and LOAEL values for fish and wildlife via bioaccumulation (Table 5.5-1). High waterborne Se concentrations were reflected in elevated concentrations in limited fish samples collected in 1998. Median Se concentration in fish collected at this location exceeded typical background levels by a factor of approximately 13 and were far in excess of threshold concentrations established for dietary exposure for both breeding and non-breeding avian species.

Naturally-elevated Se concentrations in environmental media at Area X necessitate careful monitoring if construction of brine collection facilities is ever completed at this location. Monitoring should be conducted to evaluate potential increases in Se concentrations in a variety of matrices as a result of brine collection and pumping activities. While identically-constructed collection facilities at Area VIII appear to have had minimal impacts on Se increases, this evaluation should be conducted on a site-specific basis at Area X. In addition, monitoring activities should evaluate potential increased use by avian species as a result of facility construction as current Se concentrations appear to be at levels that could potentially impact these species.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on results of selenium monitoring activities during 1997 and 1998 at Truscott Brine Lake and associated brine collection areas, the following overall conclusions and recommendations are provided:

(1) Following approximately eleven (11) years of project operation, selenium concentrations in samples of water, sediment, fish, and limited samples of aquatic vegetation from Truscott Brine Lake were at or below “background” concentrations typical for these media in selenium-normal environments as well as below published threshold levels for protection of avian species. Similarly, Se concentrations in samples of eggs, livers, and ingested food of sedentary insectivorous birds (red-winged blackbirds) approximated background concentrations and were below threshold values established in the literature as protective of reproductive effects. For mobile piscivorous birds (great blue herons and double-crested cormorants), Se concentrations in eggs were higher with concentrations in some eggs exceeding both background concentrations and reproductive impairment threshold levels. While not the most appropriate species for Se impact evaluation owing to their mobility, these birds were the only piscivorous species observed nesting at Truscott Lake. Evaluation of limited Se concentration data from aquatic environments surrounding Truscott Lake, where naturally-occurring concentrations were much higher, provided a conceivable explanation for elevated Se concentrations in eggs of mobile bird species nesting at the impoundment. Based on these findings, it is possible that Truscott Lake provided Se-related benefits to populations of mobile avian species feeding both in the lake and in surrounding environments where concentrations were elevated. As long as these trends continue, Truscott Lake may provide future Se-related benefits to some populations of avian species in the project area.

(2) While extensive bird use surveys over a two year period revealed that while Truscott Lake and the surrounding area received use by a wide variety of bird species, nesting by semi-aquatic birds was limited to only a few avian species. For these species, nest numbers were likewise limited. While certainly not the only Se-induced reproductive impact known to occur among birds, post-hatch monitoring of nestlings revealed no evidence of malformations characteristic of Se toxicity, even in nests of mobile piscivorous species with elevated Se concentrations in eggs.

(3) Results of monitoring at Truscott Brine lake are applicable for the monitoring period only and should not be interpreted to represent current or future conditions. The potential for increasing Se concentrations as the project progresses and complexities involved with Se dynamics are justification for continued monitoring of a variety of environmental media at Truscott Lake. This is particularly true if additional brine sources are added as input to the impoundment. This monitoring will provide an

increased understanding of site-specific Se dynamics and permit future risk / impact assessment as the project progresses.

(4) Monitoring results at the one operational brine collection facility (Area VIII on the South Fork of the Wichita River) revealed that waterborne Se concentrations were above background at this location, below the range of concern for avian species, and near the low end of the range of concern for fish and wildlife via bioaccumulation. Selenium concentrations in water and fish were similar in the brine collection pool and a sampling site upstream of the facility. For fish, concentrations were lower downstream of the facility indicating that mass removal may be providing some downstream Se-related benefits. Extensive bird survey results over the two year monitoring period failed to identify any semi-aquatic nesting birds at the pump station – an indication that construction of the facility did not provide a significant attractant for semi-aquatic breeding birds during the monitoring period.

(5) Limited monitoring results from a partially-constructed, potential future brine collection area (Area X on the Middle Fork of the Wichita River) revealed high Se concentrations in both water and fish at this location. Naturally-elevated Se concentrations at this location necessitate careful site-specific monitoring if construction of brine collection facilities is ever completed at Area X. This monitoring should be conducted to evaluate potential increases in Se concentrations in a variety of matrices as a result of brine collection and pumping activities. In addition, monitoring activities should evaluate potential increased use by avian species as a result of facility operation as current Se concentrations appear to be at levels that could potentially impact these species.

(6) As the project progresses, further monitoring of Se concentrations in a variety of environmental matrices is definitely warranted. Results of monitoring efforts described in this report should help guide future selenium monitoring efforts for the project.

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Appendix A

Bird Survey Report

Avian Community Dynamics at Truscott Brine Lake

Lisa Wrinkle and C. Brad Dabbert
Texas Tech University

Final Report

Prepared For:
U.S. Army Corps of Engineers, Tulsa District

DRAFT

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DRAFT

PROJECT TITLE: Avian Community Dynamics at Truscott Brine Lake and Area VIII

ORGANIZATION: Department of Range, Wildlife, and Fisheries Management
Texas Tech University, Lubbock, TX 79409-2125

DATE OF INITIATION: January 1997

COMPLETION DATE: August 1999

INVESTIGATORS: C. Brad Dabbert, principal investigator and Lisa Wrinkle, research assistant

PURPOSE: Estimation of bird use at Truscott Brine Lake and Area VIII and subsequent determination of potential impacts to avian species related to potential exposure to selenium. As requested by the Tulsa District, we extracted portions of the methods and results sections of a thesis written by Ms. Lisa Wrinkle, to prepare this report.

OBJECTIVES:

1. Assess the composition of both the breeding and nonbreeding bird communities at the sites to determine the potential magnitude of the impact of selenium toxicity on birds

2. Determine what species of birds would be most appropriate for selenium evaluation

3. Determine egg selenium burdens and potential effects on neonatal survival and development of those target species selected in Objective 2.

MATERIALS AND METHODS

Assessing Breeding and Nonbreeding Bird Composition

Breeding Bird Community Composition

Point count surveys were conducted to determine characteristics of the breeding bird communities at the sites. The point count surveys provided information about species richness, diversity, and breeding bird abundance. The surveys were conducted, once per month during the last four days of each month in May through August 1997 and April through August 1998. Point locations were established at every 1,000-m interval around Truscott Brine Lake for a total of 20 points. Only one point per area was established for Area VIII and the freshwater ponds due to their small size. Each point was marked by placing a ten-foot PVC-pipe pole into the ground at the land/water interface. When the water level fluctuated, a point was defined as the location where the land and water met to form a straight line with the PVC pipe and the center of the lake. The actual point count surveys were conducted in accordance with standard methods previously described by Ralph et al. (1995). Briefly, points were divided between the last four days of the month in order to survey at every point within the first three hours after sunrise. All birds heard or seen for an infinite distance from the point were recorded. Identification of unknown birds after the count was limited to 10 minutes.

Analysis of the point count survey data included the determination of species richness, which was defined as the number of species found in a sample of individuals. Total species richness at each site was determined using point count survey data, winter inventory data, and incidental sightings. In addition, diversity (eveness of the distribution of individuals among species) was calculated using a heterogeneity index, specifically a modification of Simpson's index. The index was calculated by the following formula: D = 1-L, where L = Σ [n_i (n_I-1) / N (N- 1)] and n_i = the number of individuals of a particular species, N = the total number of individuals. The index varies from 0 to 1 with values closer to 1 representing more diverse sites (Morrison et al. 1992). Lastly, point count survey data were used to calculate the average abundance of individual species at each study site. It was assumed that all species had the same detectability across all habitats within a site. We calculated the mean number of detections of a species at a point from the 4 (1997) or 5 (1998) monthly visits within a field season. The average abundance of a species at Truscott Brine Lake was then calculated as the mean number of the 20 point means. As a consequence of having only one point each at Area VIII and the freshwater ponds, the mean number of detections of a species at the site was calculated rather than average abundance.

Nonbreeding Bird Community Composition

The wintering bird community at the sites was also characterized. Density was determined using optical field of view sampling conducted once per month during the last week of each month in November-February (1997-1998 season) and OctoberNovember (1998 season). The sampling consisted of standing at a strategically placed point around the site and estimating the number of birds present using binoculars or a spotting scope. At each point, the number of birds in the first field of view of the binoculars was counted. Then, the number of fields of view at that point were counted and multiplied by the number of birds in the first field of view to estimate the number of birds present. During the counts, emphasis was placed on identifying waterfowl and other birds occupying the water. Four categories including ducks, American coots, geese, and grebes were established. When birds could not be identified as being either a duck or an American coot, both groups were combined into a fifth group noted as "combination." At each site, monthly absolute density of birds in each of the five categories was estimated by adding the individual point totals together. Also, the monthly total density of all birds counted per sight per season, regardless of category, was estimated.

Preliminary Assessment of Target Species to be Studied

Because of selenium's biomagnification properties, two levels in the aquatic food chain (piscivorous and insectivorous birds) were examined to determine differences in dietary selenium concentrations between trophic levels. Intensive nest searching for sedentary, aquatic and semi-aquatic bird species was conducted at the sites. The goal was to find species actively involved in aquatic environments through feeding practices because these would be most appropriate for selenium evaluations. As a result of these searches, such birds were sighted (e.g., grebes); however, they were not observed nesting at any of the sites. Consequently, the two piscivorous species chosen for investigation were the only semi-aquatic, piscivorous bird species nesting in groups of more than one or two pairs at the sites. They were the great blue heron *(Ardea herodias)* and the double-crested cormorant *(Phalacrocorax auritus*). While these species were not the most appropriate for selenium evaluation due to their non-sedentary behaviors, they were the only species present. In fact, these two species were only available at one of the three sites, Truscott Brine Lake. During the study, no birds were observed nesting at Area VIII despite intensive nest searching, and only the insectivorous species was found nesting at the largest freshwater pond. The insectivorous species chosen for this study was the red winged blackbird *(Agelaius phoeniceus).* It was chosen because of its dependence on aquatic-based foods during the breeding season and its preference for nesting in wetland areas. The three above-mentioned species were considered the target species for this study.

Nest Searching and Egg Collection

Nest searching and egg collection were conducted from May 20 to June 11, 1997 and from April 19 to June 14, 1998 to determine egg selenium levels found in the three target species. Nests of the red-winged blackbirds were located by searching in cattail (*Typha spp.*) and decadent juniper stands around the perimeter of the sites. In addition, nests of double-crested cormorants and great blue herons were located by searching the rookeries contained within the site. Once active nests were identified, they were mapped using a global positioning system (GPS) and marked a safe distance away to avoid predator attraction.

Egg collection began when egg laying was initiated. One egg per nest was randomly collected then wrapped in protective plastic and placed in a styrofoam cup to prevent damage or breakage. Eggs were then placed on ice for transport back to the lab for immediate processing. External contamination of egg samples was prevented by wearing latex gloves and washing the egg exterior with distilled water and a soft brush. Egg length, width, and total weight to the nearest 0.01 (cm or g) were determined after cleaning. Subsequently eggs were cut at the air sac end using a circular motion to remove a small piece of the eggshell. Egg contents were emptied into sterile jars and weighed to the nearest 0.0 1 gram. Eggshell weight was determined by subtraction. Jars were secured using a tamper proof seal and stored at –20 °C until analysis. Samples were sent to the Environmental Trace Substances Laboratory in Rolla, Missouri for analysis. Acid digestion and atomic absorption were used to determine total selenium content of samples. The samples were freeze-dried first to obtain dry-weight measurements (Hartman 1997).

Monitoring Reproductive Success

After egg collection, nests and remaining eggs were monitored throughout the nesting period to determine reproductive success. Each nest was checked at least every four days, and the number of eggs and nestlings in each nest was recorded. Nestlings were carefully examined for malformations characteristic of selenium toxicity such as abnormal eye size, twisted feet and legs, missing appendages, and deformed bills (Ohlendorf et al. 1986b). Monitoring continued until all of the nestlings had fledged. A successful nest was considered to be one from which at least one nestling fledged. Nest success was calculated using the Mayfield Method (Mayfleld 1975). The lengths of incubation and nestling periods were assumed to be as follows for the three target species: red-winged blackbird = 11 and 13 days, great blue heron = 28 and 58 days, double-crested cormorant = 27 and 39 days, respectively (Ehrlich et al. 1988). A z-statistic was computed and used to determine differences in daily survival estimates between 1997 and 1998 within a species for both incubation and nestling periods at Truscott Brine Lake. The z-statistic was also used to determine differences in daily survival estimates of red-winged blackbirds between the freshwater pond and Truscott

Brine Lake for both periods (Johnson 1979). Initial analysis showed no differences in daily survival estimates between years for birds at Truscott Brine Lake. Therefore, data were pooled within a species across the two years, and a z-statistic was used to test for differences in daily survival estimates among the three target species.

RESULTS

Assessing Breeding and Nonbreeding Bird Composition

Breeding Bird Community Composition Results

Total species richness at Truscott Brine Lake for both 1997 and 1998 combined was 113 species representing 31 families. One federally and state endangered species was recorded at the lake in both 1997 and 1998, the interior least tern *(Sterna antillarum athalassos).* The average abundance of the interior least tern was 0.0 125 mean number of birds per point in 1997 and 0.14 mean number of birds per point in 1998. No tern nests were found; however, terns were observed feeding at the lake on two different occasions. Total species richness at Area VIII and the freshwater ponds was 37 and 57 representing 17 and 26 families, respectively. Monthly species richness at Truscott Brine Lake ranged from 31 to 52 with peaks during April and May. Species richness at the freshwater ponds ranged from 12 to 22 with peaks during July and August. Species richness at Area VIII peaked during May and June, and the number of species ranged from 7 to 13. Yearly species richness increased from 1997 to 1998 at all three sites.

Diversity at Area VIII peaked in May of 1997 and in July of 1998. Freshwater Pond I (the largest pond) had peak diversity in July of 1997 and April of 1998. In contrast, diversity at Freshwater Pond 2 peaked during May of 1998. Yearly diversity was similar between 1997 and 1998 at Truscott Brine Lake and Area VIII. However, diversity at Freshwater Pond I was lower in 1998 than in 1997.

Average abundance (mean number of birds per point) of individual species at Truscott Brine Lake ranged from 0.0125 to 5.325 in 1997 and from 0.01 to 4.84 in 1998. At Area VIII, mean number of detections in 1997 ranged from 0.25 to 3.25 and in 1998 from 0.2 to 6.4. Mean number of detections at Freshwater Pond 1 ranged from 0.33 to 9.67 in 1997 and 0.2 to 56.8 in 1998. Freshwater Pond 2, evaluated only in 1998, had a mean number of detections ranging from 0.2 to 21.8.

Eight species had an average abundance above one at Truscott Brine Lake in 1997. They included cattle egret *(Bubulcus ibis*) (5.325), mourning dove *(Zenaida macroura)* (2.275), mallard *(Anas platyrhynch*os) (1.9625), red-winged blackbird (1.7), double-crested cormorant (1.475), Bewick's wren *(Thryomanes bewickii)* (1.3625), northern mockingbird *(Mimus polyglottos)* (1. 2375), and great egret *(Casmerodius albus)* (1.05). In 1998, eleven species at the lake had an average abundance higher than one. They included mallard (4.84), blue-winged teal *(Anas discors)* (3.76), cattle egret (3.41), red-winged blackbird (3.32), mourning dove (3.03), double-crested cormorant (2.11), tree swallow *(Tachycineta bicolor)* (1.7), great egret (1.59), snowy egret *(Egretta thula)* (1.4 1), Bewick's wren (1.24), and northern mockingbird (1.23).

The five most abundant species at Area VIII in 1997, beginning with the most abundant, were mourning dove, Bewick's wren, scissor-tailed flycatcher *(Tyrannus forficatus),* northern mockingbird, and ash- throated flycatcher *(Myiarchus cinerascens).* In 1998, the five most abundant species were turkey vulture *(Cathartes aura),* mourning dove, great-tailed grackle *(Quiscalus mexicanus*), Bewick's wren, and scissor-tailed flycatcher. In 1997, at Freshwater Pond 1, mourning dove, red-winged blackbirds, blue-winged teal, lark sparrows *(Chondestes grammacus)* and northern bobwhite *(Colinus virginianus)* were the most abundant species. In 1998, tree swallows, mourning dove, blue-winged teal, red-winged blackbirds, and ruddy ducks *(Oxyura jamaicensis)* had the highest abundance estimates. At Freshwater Pond 2, only evaluated in1998, the most abundant species included mourning dove, blue-winged teall, red-winged blackbirds, mallards, and white-faced ibis *(Plegadis chihi).*

Nonbreeding Bird Community Composition Results

Monthly absolute density (birds/ha) for each of the five categories of birds was estimated for each site. The highest density for ducks, American coots, combination, and grebes during the 1997-1998 season occurred in the month of November at Truscott Brine Lake. The highest density for geese occurred during December. During the 1998-1999 season, again November exhibited the highest density for ducks, American coots, and grebes. Goose densities were highest in November as well. Peak density for ducks at Area VIII took place during January of the 1997-1998 season and November of the 1998-1999 season. Geese and American coots were not seen during the winter counts at Area VIII. Ducks and coots were at their highest densities during the month of November at Freshwater Pond 1, during the 1997-1998 season. Peak densities for geese occurred during December. In the 1998-1999 season, American coot and grebe densities reached the highest point in November, and duck densities were similar throughout the sampling period. Freshwater Pond 2 had the highest duck densities during December and October in 1997-1998 and 1998-1999, respectively. Truscott Brine Lake exhibited the greatest estimated density of birds with the highest densities occurring in November of both seasons.

Nest Searching and Egg Collection Results

During the 1997 field season, a total of 7 great blue heron, 6 double-crested cormorant, and 12 red-winged blackbird nests was monitored at Truscott Brine Lake. Eight red-winged blackbird nests were monitored at the freshwater pond in 1997. During the 1998 field season, a total of 8 great blue heron, 11 double-crested cormorant, and 5 red-winged blackbird nests was monitored at the lake. Seven red-winged blackbird nests were monitored at the freshwater pond in 1998.

Mean egg weight of great blue heron eggs in 1997 was 61.44 grams and 69.03 grains in 1998. Double-crested cormorant eggs had a mean total egg weight of 43.33 g and 45.24 g in 1997 and 1998, respectively. At Truscott Brine Lake, red-winged blackbird total egg weights averaged 3.64 g in 1997 and 3.78 g in 1998. Red-winged blackbird total egg weights at the freshwater pond averaged 3.82 g in 1997 and 4.12 g in 1998.

Egg selenium levels of great blue herons found at Truscott Brine Lake ranged from 3.0 ppm to 18 ppm in 1997 and from 1.9 ppm to 8.8 ppm in 1998. Double-crested cormorant egg selenium levels ranged from 2.4 ppm to 18 ppm in 1997 and from 2.5 ppm to 9.4 ppm in 1998. Red-winged blackbird egg selenium levels from Truscott Brine Lake ranged from 2.1 ppm to 3.2 ppm in 1997 and from 2.3 ppm to 3.2 ppm in 1998. Egg selenium levels of red-winged blackbirds collected at the freshwater pond ranged from 2.0 ppm to 3.0 ppm in 1997 and from 2.0 ppm to 3.0 ppm again in 1998. All ranges are presented on a dry weight basis. Geometric mean egg selenium levels in 1997 were great blue heron = 5.8 ppm (dry weight), double-crested cormorant = 5.4 ppm, red-winged blackbirds at the lake = 2.8 ppm, red-winged blackbirds at the pond = 2.5 ppm. Geometric means in 1998 were as follows, herons = 3.7 ppm, cormorants = 4.9 ppm, redwings at the lake = 2.7 ppm, and redwings at the pond = 2.7 ppm. Of the 15 great blue heron eggs collected at Truscott Brine Lake over the two years of the study, 13% had selenium levels exceeding the threshold value of 10 ppm (dry weight) in eggs, and 8% of the 17 double-crested cormorant eggs exceeded the threshold. No red-winged blackbird eggs (n= 17) collected at Truscott Brine Lake had selenium levels exceeding the threshold value.

Reproductive Success Results

Nest success for the three target species was calculated for both 1997 and 1998. About 15% and 20% of great blue heron nests beginning incubation were expected to survive through the end of the nestling period in 1997 and 1998, respectively. In 1997, approximately 3% of double-crested cormorant nests were expected to survive. In 1998, the percentage increased to 61%. Nest survival of red-winged blackbirds at Truscott Brine Lake decreased from 39% in 1997 to only 4% in 1998. In contrast, nests of blackbirds at the freshwater pond had about 2% survival in 1997, but 17% survival in 1998. Daily survival estimates of piscivorous birds during incubation were higher (P <0.05) than insectivorous birds (Z=2.60). Daily survival estimates of double-crested cormorants and great blue herons during the nestling period were not different ($P < 0.05$) (Z=0.611). The red-winged blackbird's daily survival estimate during the nestling period was not compared to the others because the estimate was 1.00. No variance existed for this estimate; and therefore, the z-statistic could not be properly calculated.

Table 1.1: Taxonomical total species list at Truscott Brine Lake
for 1997 and 1998 combined.
(includes point count survey (P), winter inventory (W), and incidental sighting (1) data)

Taxonomical Class	Method Used to Sight Species
Accipitridae	
Mississippi Kite (Ictinia mississippiensis)	P
Northern Harrier (Circus cyaneus)	W
Osprey (Pandion haliaetus)	P,I
Red-tailed Hawk (Buteo jamaicensis)	P
Swainson's Hawk (Buteo swainsoni)	P
Alcedinidae	
Belted Kingfisher (Ceryle alcyon)	P
Anatidae	
American Wigeon (Anas americana)	W
Blue-winged Teal (Anas discors)	P,W
Bufflehead (Bucephala albeola)	W
Canada Goose (Branta canadensis)	W
Canvasback (Aythya valisineria)	P,W
Common Goldeneye (Bucephala clangula)	W
Gadwall (Anas strepera)	P,W
Greater Scaup (Aythya marila)	W
Greater White-fronted Goose (Anser albifrons)	W
Green-winged Teal (Anas crecca)	P,W
Hooded Merganser (Lophodytes cucullatus)	W
Lesser Scaup (Aythya affinis)	W
Mallard (Anas platyrhynchos)	P,W
Mute Swan (Cygnus olor)	P
Northern Pintail (Anas acuta)	W
Northern Shoveler (Anas clypeata)	P,W
Redhead (Aythya americana)	W
Ring-necked Duck (Aythya collaris)	W
Ruddy Duck (Oxyura jamaicensis)	P,W
Apodidae	
Chimney Swift (Chaetura pelagica)	P
Ardeidae	
Black-crowned Night Heron (Nycticorax nycticorax)	P
Cattle Egret (Bubulcus ibis)	P
Great Blue Heron (Ardea herodias)	P
Great Egret (Casmerodius albus)	P
Green-backed Heron (Butorides striatus)	P
Little Blue Heron (Egretta caerulea)	P,I
Snowy Egret (Egretta thula)	P

Table 1.1. Continued.

Taxonomical Class	Method Used to Sight Species
Caprimulgidae	
Common Nighthawk (Chordeiles minor)	P
Cathartidae	
Turkey Vulture (Cathartes aura)	P
Charadriidae	
Plover spp. (Charadrius)	P
Killdeer (Charadrius vociferus)	
	P
Columbidae	
Mourning Dove (Zenaida macroura)	P
Corvidae	
American Crow (Corvus brachyrhynchos)	P
Blue Jay (Cyanocitta cristata)	P
Cuculidae	
Greater Roadrunner (Geococcyx californianus)	P
Yellow-billed Cuckoo (Coccyzus americanus)	P
Emberizidae	
American Tree Sparrow (Spizella arborea)	P
Blue Grosbeak (Guiraca caerulea)	P,I
Brown-headed Cowbird (Molothrus ater)	P
Cassin's Sparrow (Aimophila cassinii)	P
Chipping Sparrow (Spizella passerina)	P
Common Grackle (Quiscalus quiscula)	I
Dark-eyed Junco (Junco hyemalis)	I
Eastern meadowlark (Sturnella magna)	P
Field Sparrow (Spizella pusilla)	P
Grasshopper Sparrow (Ammodramus savannarum)	P
Great-tailed Grackle (Quiscalus mexicanus)	P
Indigo Bunting (Passerina cyanea)	P
Lark Sparrow (Chondestes grammacus)	P
Northern Cardinal (Cardinalis cardinalis)	P
Northern Oriole (Bullock's) (Icterus galbula)	P
Painted Bunting (Passerina ciris)	P
Red-winged Blackbird (Agelaius phoeniceus)	P
Rufous-crowned Sparrow (Aimophila ruficeps)	P
Savanna Sparrow (Passerculus sandwichensis)	W
Unknown Sparrow spp.	P
Western Meadowlark (Sturnella neglecta)	I
White-crowned Sparrow (Zonotrichia leucophrys)	P

Table 1. 1: Continued.

Taxonomical Class	Method Used to Sight Species
Emberizidae Continued	
White-throated Sparrow (Zonotrichia albicollis)	P
Yellow Warbler (Dendroica petechia)	P
Yellow-headed Blackbird (Xanthocephalus xanthocephalus)	P
Falconidae	
American Kestrel (Falco sparverius)	P,I
Fringillidae	
American Goldfinch (Carduelis tristis)	
Gaviidae	
Common Loon (Gavia immer)	P,I
Hirundinidae	
Barn Swallow (Hirundo rustica)	P
Tree Swallow (Tachycineta bicolor	P
Laniidae	
Loggerhead Shrike (Lanius ludovicianus)	I
Laridae	
Black Tern (Childonias niger)	
Laughing Gull (Larus atricilla)	P
Least Tern (Sterna antillarum)	P
Mimidae	
Northern Mockingbird (Mimus polyglottos)	P
Pelecanidae	
American White Pelican (Pelecanus erythrorhynchos)	P,I
Phalacrocoracidae	
Double-crested Cormorant (Phalacrocorax auritus)	P
Phasianidae	
Chukar (Alectoris chukar)	1*
Northern Bobwhite (Colinus virginianus)	P
Ring-necked Pheasant (Phasianus colchicus)	1*
Wild Turkey (Meleagris gallopavo)	P

NOTE: 1* = The USACE released these two species at the lake

Table 1.1: Continued.

Taxonomical Class	Method Used to Sight Species
Picidae	
Downy Woodpecker (Picoides pubescens)	
Golden-fronted Woodpecker (Melanerpes aurifrons)	P
Ladder-backed Woodpecker (Picoides scalaris)	P
Northern Flicker (Colaptes auratus)	P
Red-bellied Woodpecker (Melanerpes carolinus)	I
Podicipedidae	
Eared Grebe (Podiceps nigricollis)	P
Homed Grebe (Podiceps auritus)	I
Pied-billed Grebe (Podilymbus podiceps)	P
Western Grebe (Aechmophorus occidentalis)	P
Rallidae	
American Coot(Fulica americana)	P,W
Recurvirostridae	
American Avocet (Recurvirostra americana)	P
Black-necked Stilt (Himantopus mexicanus)	P,W
Scolopacidae	
Greater Yellowlegs (Tringa melanoleuca)	P,W
Least Sandpiper (Calidris minutilla)	P
Long-billed Curlew (Numenius americanus)	P
Long-billed Dowitcher (Limnodromus scolopaceus)	P
Sanderling (Calidris alba)	P
Spotted Sandpiper (Actitis macularia)	P
Upland Sandpiper (Bartramia longicauda)	P,I
Whimbrel (Numenius phaeopus)	P
Strigidae	
Great Horned Owl (Bubo virginianus)	P,I
Threskiornithidae	
White-faced Ibis (Plegadis chihi)	P
Troglodytidae	
Bewick's Wren (Thryornanes bewickii)	P
Carolina Wren (Thryothorus ludovicianus)	P
Tyrannidae	
Ash-throated Flycatcher (Myiarchus cinerascens)	P
Eastern Kingbird (Tyrannus tyrannus)	P
Eastern Phoebe (Sayornis phoebe)	P
Great-crested Flycatcher (Myiarchus crinitus)	P
Scissor-tailed Flycatcher (Tyrannus forficatus)	P
Western Kingbird (Tyrannus verticalis)	P

Table 1.2: Taxonomical total species list at Area VIll
for 1997 and 1998 combined.
(includes point count survey (P), winter inventory (W), and incidental sighting (1) data)

Taxonomical Class	Method Used to Sight Species
Alcedinidae	
Belted Kingfisher (Ceryle alcyon)	P
Anatidae	
American Wigeon (Anas americana)	W
Blue-winged Teal (Anas discors)	W,I
Common Goldeneye (Bucephala clangula)	W
Lesser Scaup (Aythya affinis)	W
Northern Shoveler (Anas clypeata)	W
Ring-necked Duck (Aythya collaris)	W,I
Ruddy Duck (Oxyura jamaicensis)	W
Ardeidae	
Great Blue Heron (Ardea herodias)	P
Green-backed Heron (Butorides striatus)	P
Snowy Egret (Egretta thula)	P
Caprimulgidae	
Common Nighthawk (Chordeiles minor)	P
Cathartidae	
Turkey Vulture (Cathartes aura)	P
Charadriidae	
Killdeer (Charadrius vociferus)	
Columbidae	
Mourning Dove (Zenaida macroura)	
Emberizidae	
American Tree Sparrow (Spizella arborea)	P
Brown-headed Cowbird (Molothrus ater)	P
Dark-eyed Junco (Junco hyemalis)	I
Eastern meadowlark (Sturnella magna)	P
Great-tailed Grackle (Quiscalus mexicanus)	P
Indigo Bunting (Passerina cyanea)	I
Lark Sparrow (Chondestes grammacus)	P
Northern Cardinal (Cardinalis cardinalis)	P
Northern Oriole (Bullock's) (Icterus galbula)	P
Red-winged Blackbird (Agelaius phoeniceus)	P
Unknown Sparrow spp.	P
Mimidae	
Northern Mockingbird (Mimus polyglottos)	P

Table 1.2: Continued.

Taxonomical Class	Method Used to Sight Species
Paridae	
Tufted Titmouse (Parus bicolor)	P
Phalacrocoracidae	
Double-crested Cormorant (Phalacrocorax auritus)	
Phasianidae	
Northern Bobwhite (Colinus virginianus)	P
Picidae	
Golden-fronted Woodpecker (Melanerpes aurifrons)	P
Podicipedidae	
Eared Grebe (Podiceps nigricollis)	W
Scolopacidae	
Greater Yellowlegs (Tringa melanoleuca)	P
Troglodytidae	
Bewick's Wren (Thryornanes bewickii)	P
Tyrannidae	
Ash-throated Flycatcher (Myiarchus cinerascens)	P
Scissor-tailed Flycatcher (Tyrannus forficatus)	P

Table 1.3: Taxonomical total species list at the freshwater ponds for 1997 and 1998 combined.
(includes point count survey (P), winter inventory (W), and incidental sighting (I) data)

Taxonomical Class	Method Used to Sight Species
Accipitridae	
Osprey (Pandion haliaetus)	I
Alcedinidae	
Belted Kingfisher (Ceryle alcyon)	P
Anatidae	
American Wigeon (Anas americana)	W
Blue-winged Teal (Anas discors)	P,W
Bufflehead (Bucephala albeola)	W
Canada Goose (Branta canadensis)	W
Canvasback (Aythya vallsineria)	W
Gadwall (Anas strepera)	W
Green-winged Teal (Anas crecca)	P,W
Hooded Merganser (Lophodytes cucullatus)	W
Lesser Scaup (Aythya affinis)	W
Mallard (Anas platyrhynchos)	P,W
Mute Swan (Cygnus olor)	I
Northern Pintail (Anas acuta)	W
Northern Shoveler (Anas clypeata)	W
Redhead (Aythya americana)	W
Ring-necked Duck (Aythya collaris)	W
Ruddy Duck (Oxyura jamaicensis)	P,W
Ardeidae	
Black-crowned Night Heron (Nycticorax nycticorax)	P
Cattle Egret (Bubulcus ibis)	P
Great Blue Heron (Ardea herodias)	P
Great Egret (Casmerodius albus)	P
Green-backed Heron (Butorides striatus)	P
Little Blue Heron (Egretta caerulea)	P
Snowy Egret (Egretta thula)	P
Caprimulgidae	
Common Nighthawk (Chordeiles minor)	P
Cathartidae	
Turkey Vulture (Cathartes aura)	P
Charadriidae	
Killdeer (Charadrius vociferus)	P
Columbidae	
Mourning Dove (Zenaida macroura)	P

Table 1.3: Continued.

Taxonomical Class	Method Used to Sight Species
Corvidae	
American Crow (Corvus brachyrhynchos)	P
Cuculidae	
Greater Roadrunner (Geococcyx californianus)	P
Yellow-billed Cuckoo (Coccyzus americanus)	P
Emberizidae	
American Tree Sparrow (Spizella arborea)	I
Brown-headed Cowbird (Molothrus ater)	P
Cassin's Sparrow (Aimophila cassinii)	P
Chipping Sparrow (Spizella passerina)	I
Common Grackle (Quiscalus quiscula)	I
Eastern meadowlark (Sturnella magna)	P
Great-tailed Grackle (Quiscalus mexicanus)	P
Lark Sparrow (Chondestes grammacus)	P
Northern Cardinal (Cardinalis cardinalis)	P
Northern Oriole (Bullock's) (Icterus galbula)	I
Red-winged Blackbird (Agelaius phoeniceus)	P
Yellow-headed Blackbird (Xanthocephalus xanthocephalus)	P
Yellow-rumped Warbler (Dendroica coronata)	P
Hirundinidae	
Tree Swallow (Tachycineta bicolor)	P
Laniidae	
Loggerhead Shrike (Lanius ludovicianus)	I
Laridae	
Laughing Gull (Larus atricilla)	I
Mimidae	
Northern Mockingbird (Mimus polyglottos)	P

Table 1.3: Continued.

Taxonomical Class	Method Used to Sight Species
Pelecanidae	
American White Pelican (Pelecanus erythrorhynchos)	
Phalacrocoracidae	
Double-crested Cormorant (Phalacrocorax auritus)	P
Phasianidae	
Northern Bobwhite (Colinus virginianus)	P
Picidae	
Ladder-backed Woodpecker (Picoides scalaris)	P
Podicipedidae	
Eared Grebe (Podiceps nigricollis)	P
Pied-billed Grebe (Podilymbus podiceps)	P
Rallidae	
American Coot (Fulica americana)	P,W
Recurvirostridae	
American Avocet (Recurvirostra americana)	P
Black-necked Stilt (Himantopus mexicanus)	P
Scolopacidae	
Greater Yellowlegs (Tringa melanoleuca)	P
Spotted Sandpiper (Actitis macularia)	P
Threskiornithidae	
White-faced Ibis (Plegadis chihi)	P
Troglodytidae	
Bewick's Wren (Thryomanes bewickii)	P
Tyrannidae	
Ash-throated Flycatcher (Myiarchus cinerascens)	P
Scissor-tailed Flycatcher (Tyrannus forficatus)	P

Table 1.4. Monthly species richness estimated from point count survey data at three sites in the Texas rolling plains for both 1997 and 1998.

Site	April[a]	May[b]	June	July	August
Truscott Brine Lake					
1997	NA	40	31	35	37
1998	52	45	39	44	43
Freshwater Ponds					
1997	NA	NA	12	17	12
1998	17	20	20	22	21
Area VIII					
1997	NA	9	10	7	7
1998	11	13	9	9	10

[a] = Point Count Surveys were not conducted in April 1997
[b] = Point Count Surveys were not conducted at the Freshwater Ponds in May 1997

Table 1.5. Monthly diversity estimates calculated from point count survey data at four sites in the Texas rolling plains for both 1997 and 1998.

Site	April[a]	May[b]	June	July	August
Truscott Brine Lake					
1997	NA	0.9403	0.9449	0.8272	0.8853
1998	0.9399	0.9443	0.9433	0.9167	0.8479
Freshwater Pond 1					
1997	NA	NA	0.8739	0.9096	0.8032
1998	0.8966	0.8626	0.2076	0.6267	0.5905
Freshwater Pond 2[c]					
1997	NA	NA	NA	NA	NA
1998	0.9000	0.9109	0.88822	0.5157	0.7925
Area VIII					
1997	NA	0.9053	0.9033	0.8497	0.8462
1998	0.9239	0.9032	0.8581	0.9191	0.7230

[a] = Diversity was not calculated in April 1997
[b] = Diversity was not calculated for Freshwater Pond 1 in May 1997
[c] = Diversity was not calculated for Freshwater Pond 2 in 1997

Table 1.6. Average abundance estimates from point count survey data for Truscott Brine Lake in 1997.

Species	Average Abundance	Species	Average Abundance
American Coot	0.05	Mourning Dove	2.275
American Crow	0.6375	Mute Swan	0.0125
Ash-throated Flycatcher	0.25	Northern Bobwhite	0.8
Belted Kingfisher	0.075	Northern Cardinal	0.9
Bewick's Wren	1,3625	Northern Mockingbird	1.2375
Black-crowned Night Heron	0.0375	Northern Oriole (Bullock's)	0.025
Blue-winged Teal	0.6	Northern Shoveler	0.025
Brown-headed Cowbird	0.375	Painted Bunting	0.0125
Cassin's Sparrow	0.0125	Pied-billed Grebe	0.175
Cattle Egret	5.325	Plover Spp.	0.1125
Chimney Swift	0.0125	Red-winged Blackbird	1.7
Common Loon	0.0375	Scissor-tailed Flycatcher	0.8625
Common Nighthawk	0.5625	Snowy Egret	0.45
Double-crested Cormorant	1.475	Swainson's Hawk	0.025
Eared Grebe	0.2375	Tree Swallow	0.4875
Eastern Kingbird	0.025	Turkey Vulture	0.3875
Eastern Meadowlark	0.9875	Western Kingbird	0.0125
Gadwall	0.3	White-faced Ibis	0.0125
Golden Fronted Woodpecker	0.125	Yellow-billed Cuckoo	0.0375
Grasshopper Sparrow	0.0375	Yellow-headed Blackbird	0.125
Great Blue Heron	0.75		
Great Egret	1.05		
Great Horned Owl	0.0125		
Great-crested Flycatcher	0.0125		
Greater Roadrunner	0.2		
Greater Yellowlegs	0.9125		
Great-tailed Grackle	0.2		
Green-backed Heron	0.15		
Killdeer	- 0.9		
Ladder-backed Woodpecker	0.0125		
Lark Sparrow	0.475		
Laughing Gull	0.05		
Least Tern	0.0125		
Long-billed Curlew	0.05		
Mallard	1.9625		
Mississippi Kite	0.025		
Mourning Dove	2.275		
Mute Swan	0.0125		
Northern Bobwhite	0.8		
Northern Cardinal	0.9		

Table 1.7. Average abundance estimates from point count survey data for Truscott Brine Lake in 1998.

Species	Average Abundance	Species	Average Abundance
American Avocet	0.13	Ladder-backed Woodpecker	0.06
American Coot	0.68	Lark Sparrow	0.71
American Crow	0.32	Laughing Gull	0.86
American Kestrel	0.01	Least Tern	0.14
American Tree Sparrow	0.17	Least Sandpiper	0.6
American White Pelican	0.2	Little Blue Heron	0.24
Ash-throated Flycatcher	0.09	Long-billed Dowitcher	0.11
Barn Swallow	0.03	Mallard	4.84
Belted Kingfisher	0.19	Mourning Dove	3.03
Bewick's Wren	1.24	Northern Bobwhite	0.95
Black-crowned Night Heron	0.02	Northern Cardinal	0.62
Black-necked Stilt	0.14	Northern Flicker	0.01
Blue Grosbeak	0.02	Northern Mockingbird	1.23
Blue Jay	0.04	Northern Oriole (Bullock's)	0.01
Blue-winged Teal	3.76	Northern Shoveler	0.17
Brown-headed Cowbird	0.55	Osprey	0.01
Canvasback	0.03	Painted Bunting	0.02
Carolina Wren	0.02	Pied-billed Grebe	0.25
Cassin's Sparrow	0.28	Red-tailed Hawk	0.01
Cattle Egret	3.41	Red-winged Blackbird	3.32
Chipping Sparrow	0.01	Ruddy Duck	0.01
Common Loon	0.04	Rufous-crowned Sparrow	0.08
Common Nighthawk	0.48	Sanderling	0.19
Double-crested Cormorant	2.11	Scissor-tailed Flycatcher	0.82
Eared Grebe	0.83	Snowy Egret	1.41
Eastern Meadowlark	0.8	Spotted Sandpiper	0.01
Eastern Phoebe	0.01	Swainson's Hawk	0.03
Field Sparrow	0.02	Tree Swallow	1.7
Gadwall	0.01	Turkey Vulture	0.14
Golden Fronted Woodpecker	0.08	Unknown Sparrow Spp.	0.01
Great Blue Heron	0.89	Upland Sandpiper	0.01
Great Egret	1.59	Western Grebe	0.03
Great Horned Owl	0.01	Whimbrel	0.07
Great-crested Flycatcher	0.03	White-crowned Sparrow	0.04
Greater Roadrunner	0.12	White-faced Ibis	0.21
Greater Yellowlegs	0.34	White-throated Sparrow	0.02
Great-tailed Grackle	0.57	Wild Turkey	0.05
Green-backed Heron	0.12	Yellow Warbler	0.01
Green-winged Teal	0.01	Yellow-billed Cuckoo	0.12
Indigo Bunting	0.01		
Killdeer	0.76		

Table 1.8. Average abundance estimates from point count survey data for Area VIII in both 1997 and 1998.

1997		1998	
Species	Average Abundance	Species	Average Abundance
Ash-throated Flycatcher	2.0	American Tree Sparrow	0.4
Belted Kingfisher	0.5	Ash-throated Flycatcher	0.6
Bewick's Wren	2.75	Belted Kingfisher	0.6
Common Nighthawk	1.0	Bewick's Wren	3.0
Green-backed Heron	0.75	Brown-headed Cowbird	0.2
Killdeer	0.5	Canyon Wren	0.4
Mourning Dove	3.25	Eastern Meadowlark	0.4
Northern Bobwhite	0.25	Golden-fronted Woodpecker	0.2
Northern Cardinal	1.5	Great Blue Heron	0.6
Northern Mockingbird	2.25	Greater Yellowlegs	0.8
Red-winged Blackbird	1.0	Great-tailed Grackle	3.4
Scissor-tailed Flycatcher	2.5	Green-backed Heron	0.2
Tufted Titmouse	0.5	Killdeer	0.4
Turkey Vulture	0.25	Lark Sparrow	0.2
		Mourning Dove	3.6
		Northern Bobwhite	1.4
		Northern Cardinal	1.4
		Northern Mockingbird	1.6
		Northern Oriole (Bullock's)	0.6
		Scissor-tailed Flycatcher	2.4
		Snowy Egret	0.4
		Turkey Vulture	6.4
		Unknown Sparrow Spp.	0.2

Table 1.9. Average abundance estimates from point count survey data for Freshwater Pond 1 in both 1997 and 1998.

1997		1998	
Species	Average Abundance	Species	Average Abundance
American Crow	0.33	American Avocet	1.6
Ash-throated Flycatcher	0.33	American Coot	3.2
Belted Kingfisher	1.67	Belted Kingfisher	1.2
Bewick's Wren	1.33	Bewick's Wren	0.4
Blue-winged Teal	4.67	Blue-winged Teal	11.2
Brown-headed Cowbird	2.33	Cassin's Sparrow	0.4
Cattle Egret	0.67	Cattle Egret	1.8
Common Nighthawk	0.33	Common Nighthawk	0.2
Double-crested Cormorant	0.67	Double-crested Cormorant	0.4
Eastern Meadowlark	0.67	Eared Grebe	0.2
Great Blue Heron	0.33	Eastern Meadowlark	0.4
Great Egret	0.33	Great Blue Heron	0.2
Great-tailed Grackle	1.33	Great Egret	1.4
Green-backed Heron	0.67	Greater Roadrunner	1.2
Lark Sparrow	3.67	Greater Yellowlegs	0.2
Mallard	0.67	Green-backed Heron	0.2
Mourning Dove	9.67	Green-winged Teal	1.2
Northern Bobwhite	3.0	Killdeer	1.4
Northern Cardinal	1.0	Lark Sparrow	0.4
Northern Mockingbird	1.33	Mallard	0.8
Pied-billed Grebe	0.33	Mourning Dove	18.6
Red-winged Blackbird	6.0	Northern Bobwhite	1.6
Ruddy Duck	0.33	Northern Cardinal	1.0
Scissor-tailed Flycatcher	1.67	Northern Mockingbird	0.4
Tree Swallow	0.67	Pied-billed Grebe	1.0
Yellow-billed Cuckoo	0.33	Red-winged Blackbird	9.6
		Ruddy Duck	3.4
		Scissor-tailed Flycatcher	1.8
		Spotted Sandpiper	0.8
		Tree Swallow	56.8
		Yellow-billed Cuckoo	0.8
		Yellow-headed Blackbird	0.4
		Yellow-rumped Warbler	0.4

Table 1.10. Average abundance estimates from point count survey data for Freshwater Pond 2 in 1998.

Species	Average Abundance
American Crow	0.2
American Coot	0.6
Belted Kingfisher	0.6
Bewick's Wren	2.4
Black-crowned Night Heron	0.4
Black-necked Stilt	0.4
Blue-winged Teal	9.0
Brown-headed Cowbird	0.4
Eared Grebe	0.2
Eastern Meadowlark	0.4
Great Blue Heron	0.2
Great Egret	1.6
Greater Roadrunner	0.4
Greater Yellowlegs	1.0
Great-tailed Grackle	0.8
Green-backed Heron	1.4
Killdeer	2.4
Ladder-backed Woodpecker	0.2
Lark Sparrow	1.4
Little Blue Heron	1.4
Mallard	7.0
Mourning Dove	21.0
Northern Bobwhite	0.8
Northern Cardinal	1.6
Northern Mockingbird	0.6
Pied-billed Grebe	0.2
Red-winged Blackbird	7.6
Scissor-tailed Flycatcher	0.6
Snowy Egret	0.4
Tree Swallow	2.2
Turkey Vulture	1.8
White-faced Ibis	3.0
Yellow-billed Cuckoo	0.2

Table 1.11. Monthly nonbreeding bird densities (birds/ha) at Truscott Brine Lake for both the 1997-1998 and 1998-1999 seasons.

1997-1998 Season:

Month	Ducks	Coots	Combo.	Geese	Grebes
November	0.386	4.376	4.271	0.076	0.018
December	0.113	1.182	2.114	2.647	0.0024
January	0.084	0.837	0.708	2.171	0.015
February	0.190	1.217	0.845	0.205	0.0088

1998-1999 Season:

Month	Ducks	Coots	Geese	Grebes
October	0.837	10.536	0	0.053
November	1.076	12.311	0.0040	0.057

Table 1.12. Monthly nonbreeding bird densities (birds/ha) at Area VIII for both the 1997-1998 and 1998-1999 seasons.

1997-1998 Season:

Month	Ducks	Grebes
November	0	0.8
December	0	0
January	2.8	0
February	1.4	0

1998-1999 Season:

Month	Ducks	Grebes
October	0	0.4
November	2.0	0.4

Table 1.13. Monthly nonbreeding bird densities (birds/ha) at Freshwater Pond 1 for both the 1997-1998 and 1998-1999 seasons.

1997-1998 Season:

Month	Ducks	Coots	Combo.	Geese	Grebes
November	5.37	5.07	0	0	0.049
December	0.195	2.61	1.22	17.80	0.024
January	4.15	1.54	0	0	0
February	1.00	1.85	0	2.71	0.012

1998-1999 Season:

Month	Ducks	Coots	Grebes
October	0.902	1.66	0.049
November	0.854	4.27	0.512

Table 1.14. Monthly nonbreeding bird densities (birds/ha) at Freshwater Pond 2 for both the 1997-1998 and 1998-1999 seasons.

1997-1998 Season:

Month	Ducks	Coots
November	0	0
December	3.0	2.0
January	0.93	2.27
February	2.4	1.6

1998-1999 Season:

Month	Ducks	Coots
October	1.8	0.53
November	1.0	0.93

Table I.15. Monthly total nonbreeding bird densities (birds/ha) at four sites in the Texas Rolling Plains for both the 1997-1998 and 1998-1999 seasons.

Site	October	November	December	January	February
Truscott Brine Lake					
1997-1998	NA[a]	9.127	6.059	3.815	2.465
1998-1999	11.425	13.504	NA[b]	NA[b]	NA[b]
Freshwater Pond 1					
1997-1998	NA[a]	10.488	21.854	5.683	5.683
1998-1999	2.609	5.634	NA[b]	NA[b]	NA[b]
Freshwater Pond 2					
1997-1998	NA[a]	0	5.0	3.2	4.0
1998-1999	2.333	1.933	NA[b]	NA[b]	NA[b]
Area VIII					
1997-1998	NA[a]	0.8	0	2.8	1.4
1998-1999	0.4	2.4	NA[b]	NA[b]	NA[b]

[a] = Nonbreeding bird counts were not conducted in October of the 1997-1998 season.
[b] = Nonbreeding bird counts were conducted only in October and November of the 1998-1999 season.

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Table 1.16. Physical measurements of great blue heron eggs collected at Truscott Brine Lake for both 1997 and 1998.

1997

	Identification Label						
Measurement	1	2	3	4	5	6	7
# eggs/nest	2	2	3	3	4	3	2
Egg Length (cm)	6.3	5.98	6.45	6.24	6.63	6.15	6.24
Egg Width (cm)	4.52	4.43	4.38	4.4	4.62	4.43	4.47
Total Egg Weight (g)	62.79	46.49	60.69	61.3	75.17	61.37	62.29
Jar Weight (g)	117.95	130.86	127.14	129.38	118.88	119.41	119.45
Jar with Contents (g)	174.42	171.42	181.05	184.4	182.33	173.75	174.19
Contents Weight (g)	56.47	40.56	53.91	55.02	63.45	54.34	54.74
Shell Weight (g)	6.32	5.93	6.78	6.28	11.72	7.03	7.55

1998

	Identification Label							
Measurement	A	B	C	D	E	F	G	5
# eggs/nest	4	5	4	4	4	3	4	3
Egg Length (cm)	6.77	6.6	6.51	6.27	6.64	6.67	6.5	6.371
Egg Width (cm)	4.89	4.62	4.52	4.51	4.68	4.57	4.93	4.284
Total Egg Weight (g)	82.66	67.65	64.95	63.02	68.51	67.3	80.52	57.66
Jar Weight (g)	118.61	119.86	126.04	127.99	128.39	125.56	127.19	113.41
Jar with Contents (g)	192.79	178.72	183.53	183.9	187.86	185.32	198.51	165.3
Contents Weight (g)	74.18	58.86	57.49	55.91	59.47	59.76	71.32	51.89
Shell Weight (a)	8.48	8.79	7.46	7.11	9.04	7.54	9.2	5-77

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Table 1.17. Physical measurements of double-crested cormorant eggs collected at Truscott Brine Lake in both 1997 and 1998.

1997

	Identification Label					
Measurement	1	2	3	4	5	6
# eggs/nest	4	2	4	4	3	4
Egg Length (cm)	5.96	5.48	5.45	6.24	6.42	5.82
Egg Width (cm)	3.85	3.85	3.74	3.96	3.63	3.78
Total Egg Weight (g)	43.04	42.13	37.12	49.33	43.53	44.83
Jar Weight (g)	90.04	88.72	86.93	88.86	88.63	87.88
Jar with Contents (g)	128.07	124.48	117.54	130.25	126.22	126.56
Contents Weight (g)	38.03	35.76	30.61	41.39	37.59	38.68
Shell Weight (g)	5.01	6.37	6.51	7.94	5.94	6.15

1998

	Identification Label						
Measurement	1	2	3	4	6	G1	G2
# eggs/nest	4	4	4	4	4	2	2
Egg Length (cm)	6.174	6.276	6.16	5.778	6.182	6.34	5.92
Egg Width (cm)	3.784	3.918	3.86	3.852	3.875	3.77	3.73
Total Egg Weight (g)	42.9	51.33	44.54	44.03	48.8	43.62	41.45
Jar Weight (g)	113.34	113.38	112.74	113.1	113.06	118.52	119.6
Jar with Contents (g)	151.49	157.6	150.41	149.08	155.79	155.46	155.85
Contents Weight (g)	38.15	44.22	37.67	35.98	42.73	36.94	36.25
Shell Weight (g)	4.75	7.11	6.87	8.05	6.07	6.68	5.2

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Table 1.18. Physical measurements of red-winged blackbird eggs collected at Truscott Brine Lake in both 1997 and 1998.

1997

	Identification Label											
Measurement	1	2	3	4	5	6	7	8	9	10	11	12
eggs/nest	1	4	4	2	4	4	4	4	1	4	1	2
Egg Length (cm)	2.43	2.42	2.6	2.36	2.46	2.46	2.37	2.15	2.33	2.26	2.55	2.49
Egg Width (cm)	1.87	1.73	1.83	1.7	1.68	1.77	1.77	1.62	1.82	1.83	1.8	1.67
Total Egg Weight (g)	4.26	3.68	4.24	3.37	3.41	3.78	3.96	3.12	2.93	3.72	3.67	3.57
Jar Weight (g)	88.01	88.15	88.74	86.99	87.28	88.8	89.4	87.21	87.37	87.75	88.26	131.22
Jar with Contents (g)	91.84	91.33	92.54	89.65	90.41	91.19	92.08	89.79	89.71	91.15	91.52	134.41
Contents Weight (g)	3.83	3.18	3.8	2.66	3.13	2.39	2.68	2.58	2.34	3.4	3.26	3.19
Shell Weight (g)	0.43	0.5	0.44	0.71	0.28	1.39	1.28	0.54	0.59	0.32	0.41	0.38

1998

	Identification Label				
Measurement	A	B	J	K	L
eggs/nest	4	4	3	1	1
Egg Length (cm)	2.38	2.37	2.59	2.41	2.37
Egg Width (cm)	1.85	1.68	1.79	1.77	1.9
Total Egg Weight (g)	4.33	3.47	3.76	2.74	4.59
Jar Weight (g)	121.72	121.62	118.13	119.74	121.99
Jar with Contents (g)	125.76	124.8	120.61	121.91	125.73
Contents Weight (g)	4.04	3.18	2.48	2.17	3.74
Shell Weight (g)	0.29	0.29	1.28	0.57	0.85

Table 1.19. Physical measurements of red-winged blackbird eggs collected at the freshwater pond in both 1997 and 1998.

1997

	Identification Label							
Measurement	1	2	3	4	5	6	7	8
# eggs/nest	2	2	4	1	4	4	4	3
Egg Length (cm)	2.5	2.49	2.49	2.42	2.38	2.55	2.29	2.53
Egg Width (cm)	1.79	1.79	1.82	1.76	1.68	1.91	1.72	1.8
Total Egg Weight (g)	4.28	3.92	3.87	2.36	3.61	4.6	3.67	4.27
Jar Weight (g)	88.08	118.65	119.56	127	120.66	118.56	118.42	130.68
Jar with Contents (g)	91.76	121.74	122.6	128.93	123.93	122.77	121.53	134.39
Contents Weight (g)	3.68	3.09	3.04	1.93	3.27	4.21	3.11	3.71
Shell Weight (g)	0.6	0.83	0.83	0.43	0.34	0.39	0.56	0.56

1998

	Identification Label						
Measurement	C	D	E	F	G	H	I
# eggs/nest	3	4	4	1	2	2	2
Egg Length (cm)	2.39	2.41	2.44	2.57	2.45	2.47	2.8
Egg Width (cm)	1.87	1.86	1.7	1.76	1.84	1.76	1.76
Total Egg Weight (g)	4.4	4.45	3.49	4.16	4.3	3.91	4.13
Jar Weight (g)	121.7	122.07	121.29	122.01	122.52	121.77	121.8
Jar with Contents (g)	125.78	126.19	124.44	125.15	126.14	125.37	125.58
Contents Weight (g)	4.08	4.12	3.15	3.14	3.62	3.6	3.78
Shell Weight (g)	0.32	0.33	0.34	1.02	0.68	0.31	0.35

Table 1.20. Mean egg selenium levels (wet weight) from three species at Truscott Brine Lake, Texas.

Species	Mean Egg Selenium (ppm)	Standard Error
Great Blue Heron	1.079 a [1/]	0.1722
Double-crested Cormorant	1.005 a	0.1851
Red-winged Blackbird	0.4773 b	0.1771

I/ Means followed by the same lower case letter are not different (*P*>0.05).

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Table 1.21. Daily survival estimates for three target species monitored in both the 1997 and 1998 breeding seasons.

	Number of Nests	Failures during Incubation	Failures during Nestling	Exposure Days of Incubation	Exposure Days of Nestling	Daily [3/] Survival Estimate - Incubation	Daily [3/] Survival Estimate - Nestling	Survival for Entire Period
Great Blue Heron [1/]								
1997	7	3	1	60.5	122	0.9504 ± 0.0008	0.9918 ± 0.00007	0.1494
1998	8	2	3	83	192.5	0.9759 ± 0.0003	0.9844 ± 0.00008	0.2031
Double-crested Cormorant [1/]								
1997	6	2	3	49.5	48	0.9596 ± 0.0008	0.9375	0.0265
1998	11	3	0	163	264	0.9816 ± 0.0001	1.0000 [4/]	0.6056
Red-winged Blackbird [1/]								
1997	12	7	0	86	53	0.9186 ± 0.0009 [5/]	1.0000	0.3930
1998	5	4	0	16	12	0.7500 ± 0.0117	1.0000	0.0422
Red-winged Blackbird [2/]								
1997	8	5	2	38	13	0.8684± 0.003	0.8462 ± 0.010	0.0241
1998	7	3	2	52	24	0.9423± 0.001	0.9167 ± 0.003	0.1678

[1/] Data for birds monitored at Truscott Brine Lake. [2/] Data for birds monitored at the Freshwater Pond.
[3/] All comparisons of daily survival estimates between years within a species and a period are not different at $\alpha = 0.05$.
[4/] Comparisons were not made when at least one daily survival estimate equaled 1.0000 because a variance could not be established.
[5/] All comparisons of red-winged blackbird daily survival estimates between sites within a year are not different at $\alpha = 0.05$.

Table 1.22. Daily survival estimates combined over two years for three target species at Truscott Brine Lake.

Species	Daily Survival Estimate Incubation	Daily Survival Estimate Nestling
Great Blue Heron	0.9652 ± 0.0002a [1/]	0.9873 ± 0.00004a
Double-crested Cormorant	0.9765 ± 0.0001 a	0.9904 ± 0.00003a
Red-winged Blackbird	0.8922 ± 0.0009b	1.0000 [2/]

1/ All comparisons of daily survival estimates between species within a period followed by the same lower case letter are not different at α=0.05.
2/ Daily survival estimate not compared to others within the period because a variance could not be established and therefore a z-statistic could not be properly calculated.

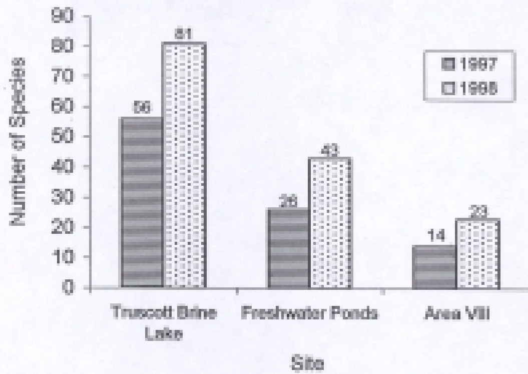

Figure 1.1 Yearly Species Richness from point count survey data at Three Sites in the Texas Rolling Plains

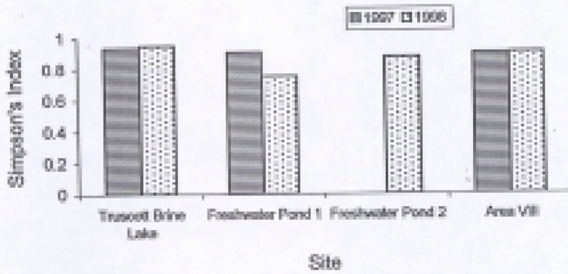

Figure 1.2. Yearly Diversity Calculated from Point Count Survey Data at Four Sites in the Texas Rolling Plains

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Appendix B

Raw Biological Data Tables

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Table B-1. Bird egg data.

DATE	SAMPLE ID	SP	LOC	LGTH(cm)	WIDTH(cm)	WT.(g)	CTS WT.(g)	% MOIST	Se (ppm dry wt)
5/20/97	TL-GBH-01	GBH	TL	6.3	4.52	62.79	56.47	83.2	4.4
5/20/97	TL-GBH-02	GBH	TL	5.98	4.43	46.49	40.56	77.9	18
5/20/97	TL-GBH-03	GBH	TL	6.45	4.38	60.69	53.91	83.2	6.1
5/20/97	TL-GBH-04	GBH	TL	6.24	4.4	61.3	55.02	81.9	3.5
5/20/97	TL-GBH-05	GBH	TL	6.63	4.62	75.17	63.45	82.5	3
5/20/97	TL-GBH-06	GBH	TL	6.15	4.43	61.37	54.34	82.9	13
5/20/97	TL-GBH-07	GBH	TL	6.24	4.47	62.29	54.74	81.1	3.3
5/20/97	TL-CMT-01	CMT	TL	5.96	3.85	43.04	38.03	84.2	3.8
5/20/97	TL-CMT-02	CMT	TL	5.48	3.85	42.13	35.76	84.9	3.8
5/20/97	TL-CMT-03	CMT	TL	5.45	3.74	37.12	30.61	83.7	18
5/20/97	TL-CMT-04	CMT	TL	6.24	3.96	49.33	41.39	83.3	2.4
5/20/97	TL-CMT-05	CMT	TL	6.42	3.63	43.53	37.59	84.8	8.7
5/20/97	TL-CMT-06	CMT	TL	5.82	3.78	44.83	38.68	84.2	4.7
5/20/97	TL-RWBB-03	RWBB	TL	2.43	1.87	4.26	3.83	81.6	2.1
5/20/97	TL-RWBB-04	RWBB	TL	2.42	1.73	3.68	3.18	86.3	2.6
5/20/97	TL-RWBB-05	RWBB	TL	2.6	1.83	4.24	3.8	83.7	2.8
5/20/97	TL-RWBB-06	RWBB	TL	2.36	1.7	3.37	2.66	82.7	2.7
5/20/97	TL-RWBB-07	RWBB	TL	2.46	1.68	3.41	3.13	83.3	2.5
5/20/97	TL-RWBB-09	RWBB	TL	2.46	1.77	3.78	2.39	81.8	2.8
5/20/97	TL-RWBB-10	RWBB	TL	2.37	1.77	3.96	2.68	84	2.7
5/30/97	TL-RWBB-11	RWBB	TL	2.15	1.62	3.12	2.58	77.2	3.2
5/30/97	TL-RWBB-12	RWBB	TL	2.33	1.82	2.93	2.34	83	2.9
6/2/97	TL-RWBB-13	RWBB	TL	2.26	1.83	3.72	3.4	83.6	3.1
6/2/97	TL-RWBB-14	RWBB	TL	2.55	1.8	3.67	3.26	80.9	2.8
6/3/97	TL-RWBB-15	RWBB	TL	2.49	1.67	3.57	3.19	83.4	3.1
6/2/97	FW-RWBB-01	RWBB	FW	2.5	1.79	4.28	3.68	82	2.6
6/2/97	FW-RWBB-02	RWBB	FW	2.49	1.79	3.92	3.09	82.1	2.7
6/2/97	FW-RWBB-03	RWBB	FW	2.49	1.82	3.87	3.04	79.6	2.5
6/2/97	FW-RWBB-04	RWBB	FW	2.42	1.76	2.36	1.93	75.8	2.3
6/11/97	FW-RWBB-05	RWBB	FW	2.38	1.68	3.61	3.27	82.6	2
6/11/97	FW-RWBB-06	RWBB	FW	2.55	1.91	4.6	4.21	83.8	2.6
6/11/97	FW-RWBB-07	RWBB	FW	2.29	1.72	3.67	3.11	81.8	2.8
6/11/97	FW-RWBB-08	RWBB	FW	2.53	1.8	4.27	3.71	83.7	3
4/19/98	TBL-GBHA-R1	GBH	TL	6.77	4.89	82.66	74.18	81.5	2.6
4/19/98	TBL-GBHB-R1	GBH	TL	6.6	4.62	67.65	58.86	82	5.2
4/19/98	TBL-GBHC-R2	GBH	TL	6.51	4.52	64.95	57.49	81.5	8.8
4/19/98	TBL-GBHD-R3	GBH	TL	6.27	4.51	63.02	55.91	81.2	5.4
4/19/98	TBL-GBHE-R4	GBH	TL	6.64	4.68	68.51	59.47	83	3.2
4/19/98	TBL-GBHF-R4	GBH	TL	6.67	4.57	67.3	59.76	81.1	2.3
4/19/98	TBL-GBHG-R4	GBH	TL	6.5	4.93	80.52	71.32	81.7	1.9
5/13/98	TBL-GBH5	GBH	TL				51.89	81.5	4

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DATE	SAMPLE ID	SP	LOC	LGTH(cm)	WIDTH(cm)	WT.(g)	CTS WT.(g)	% MOIST	Se (ppm dry wt)
5/13/98	TBL-DCC1-R2	CMT	TL	6.17	3.78	42.9	38.15	84.1	6.6
5/13/98	TBL-DCC2-R2	CMT	TL	6.28	3.92	51.33	44.22	83.9	2.5
5/13/98	TBL-DCC3-R2	CMT	TL	6.16	3.86	44.54	37.67	82.2	8
5/13/98	TBL-DCC4-R2	CMT	TL	5.78	3.85	44.03	35.98	83.7	9.4
5/13/98	TBL-DCC6-R2	CMT	TL	6.18	3.88	48.8	42.73	84.4	7.2
6/10/98	DCC-G1-TBL	CMT	TL	6.34	3.77	43.62	36.94	83.6	2.9
6/10/98	DCC-G2-TBL	CMT	TL	5.92	3.73	41.45	36.25	85.8	2.8
5/21/98	RWBB-A-TBL	RWBB	TL	2.38	1.85	4.33	4.04	86	2.4
5/21/98	RWBB-B-TBL	RWBB	TL	2.37	1.68	3.47	3.18	81.8	2.9
6/6/98	TBL-RWBB-J	RWBB	TL	2.59	1.79	3.76	2.48	88.7	3.2
6/15/98	RWBB-K-TBL	RWBB	TL	2.41	1.77	2.74	2.17	75.3	2.8
6/15/98	RWBB-L-TBL	RWBB	TL	2.37	1.9	4.59	3.74	81	2.3
5/21/98	RWBB-C-FWP	RWBB	FW	2.39	1.89	4.4	4.08	86.4	2.9
5/21/98	RWBB-D-FWP	RWBB	FW	2.41	1.86	4.45	4.12	84.6	2
5/29/98	RWBB-E-FWP	RWBB	FW	2.44	1.7	3.49	3.15	83.3	3
5/29/98	RWBB-F-FWP	RWBB	FW	2.57	1.76	4.16	3.14	80.2	2.9
5/29/98	RWBB-G-FWP	RWBB	FW	2.45	1.84	4.3	3.62	80.6	2.6
5/29/98	RWBB-H-FWP	RWBB	FW	2.47	1.76	3.91	3.6	83.5	2.9
5/29/98	RWBB-I-FWP	RWBB	FW	2.8	1.76	4.13	3.78	82.8	2.5

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Table B-2. Truscott Lake fish data.

DATE	SAMPLE ID	SPECIES	LOCATION	LGTH (mm)	WEIGHT (g)	SEX	%MOIST	Se (mg/Kg dry wt.)
6/10/97	TL-1-RRP-01	RRP	TL-1	42	1.59		72.6	1.7
6/10/97	TL-1-RRP-02	RRP	TL-1	38	0.98		74.7	1.9
6/10/97	TL-1-RRP-03	RRP	TL-1	33	0.616		67.4	1.5
6/10/97	TL-1-RRP-04	RRP	TL-1	36	1.005		61.4	0.61
6/10/97	TL-1-RRP-05	RRP	TL-1	31	0.617		67.8	1.1
6/10/97	TL-1-RRP-06	RRP	TL-1	35	0.523		73.7	2.6
6/10/97	TL-1-RRP-07	RRP	TL-1	40	1.282		77.5	1.9
6/10/97	TL-1-PKF-01	PKF	TL-1	43	0.944	M	77.8	2.1
6/10/97	TL-1-PKF-02	PKF	TL-1	51	1.687	F	75	1.4
6/10/97	TL-1-PKF-03	PKF	TL-1	35	0.531	M	77.2	2.2
6/10/97	TL-2-RRP-01	RRP	TL-2	44	1.691		75.2	1.7
6/10/97	TL-2-RRP-02	RRP	TL-2	45	2.155		72.9	2
6/10/97	TL-2-RRP-03	RRP	TL-2	42	1.479		76.8	2.4
6/10/97	TL-2-RRP-04	RRP	TL-2	45	1.974		75.7	1.5
6/10/97	TL-2-RRP-05	RRP	TL-2	40	1.31		75.3	2.1
6/10/97	TL-2-PKF-01	PKF	TL-2	43	1.201	F	78.1	1.9
6/10/97	TL-2-PKF-02	PKF	TL-2	38	0.892	F	77.5	1.6
6/10/97	TL-3-RRP-01	RRP	TL-3	36	0.903		75.2	2.5
6/10/97	TL-3-RRP-02	RRP	TL-3	31	0.723		74	3.3
6/10/97	TL-3-RRP-03	RRP	TL-3	35	0.859		74.2	2.4
6/10/97	TL-3-RRP-04	RRP	TL-3	33	0.682		74.2	2.4
6/10/97	TL-3-RRP-05	RRP	TL-3	33	0.664		73.9	2.1
6/10/97	TL-3-RRP-06	RRP	TL-3	31	0.753		74.1	2.2
6/10/97	TL-3-RRP-07	RRP	TL-3	29	0.498		74.2	2
6/10/97	TL-3-RRP-08	RRP	TL-3	30	0.563		71.3	2.6
6/10/97	TL-3-PKF-01	PKF	TL-3	26	0.238	F	75.2	2.9
6/10/97	TL-3-PKF-02	PKF	TL-3	26	0.238	F	73.4	1.9
7/7/98	TL-1-RRP-01	RRP	TL-1	38	0.53		71.9	2.6
7/7/98	TL-1-RRP-02	RRP	TL-1	39	0.989		75.8	2.5
7/7/98	TL-1-RRP-03	RRP	TL-1	41	1.139		77.5	3
7/7/98	TL-1-RRP-04	RRP	TL-1	36	0.816		78.3	3
7/7/98	TL-1-RRP-05	RRP	TL-1	39	0.816		74	2.2
7/7/98	TL-1-RRP-06	RRP	TL-1	36	0.888		77.9	2.5
7/7/98	TL-1-RRP-07	RRP	TL-1	39	0.856		76.2	2.8
7/7/98	TL-1-PKF-01	PKF	TL-1	67	4.592	M	72.1	2
7/7/98	TL-1-PKF-02	PKF	TL-1	39	0.707	M	76.3	2.4
7/7/98	TL-1-PKF-03	PKF	TL-1	46	0.888	F	76.2	2.5
7/7/98	TL-1-PKF-04	PKF	TL-1	41	0.808	M	74.3	1.9
7/7/98	TL-2-RRP-01	RRP	TL-2	40	1.069		73.3	2.1
7/7/98	TL-2-RRP-02	RRP	TL-2	41	1.414		76.5	1.9
7/7/98	TL-2-RRP-03	RRP	TL-2	39	0.952		73.7	1
7/7/98	TL-2-RRP-04	RRP	TL-2	39	0.705		77.7	2
7/7/98	TL-2-RRP-05	RRP	TL-2	37	0.893		73	2.2

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DATE	SAMPLE ID	SPECIES	LOCATION	LGTH (mm)	WEIGHT (g)	SEX	%MOIST	Se (mg/Kg dry wt.)
7/7/98	TL-2-RRP-06	RRP	TL-2	38	0.658		77	2.8
7/7/98	TL-2-PKF-01	PKF	TL-2	68	3.529	M	75.7	1.8
7/7/98	TL-2-PKF-02	PKF	TL-2	50	1.616	M	77.4	2
7/7/98	TL-2-PKF-03	PKF	TL-2	59	2.315	M	77.1	1.9
7/7/98	TL-2-PKF-04	PKF	TL-2	62	2.347	F	76.7	1.8
7/7/98	TL-3-RRP-01	RRP	TL-3	47	1.655		74.1	2.9
7/7/98	TL-3-RRP-02	RRP	TL-3	40	1.043		77.4	1.8
7/7/98	TL-3-RRP-03	RRP	TL-3	39	0.922		77.4	2.5
7/7/98	TL-3-RRP-04	RRP	TL-3	38	1.018		75	2.4
7/7/98	TL-3-RRP-05	RRP	TL-3	39	0.95		75.4	3.3
7/7/98	TL-3-RRP-06	RRP	TL-3	41	1.045		77.7	2.2
7/7/98	TL-3-RRP-07	RRP	TL-3	37	0.834		74.9	3.3
7/7/98	TL-3-PKF-01	PKF	TL-3	49	1.179	F	75.7	2
7/7/98	TL-3-PKF-02	PKF	TL-3	44	1.077	F	73.6	2.7
7/7/98	TL-3-PKF-03	PKF	TL-3	38	0.627	M	75.6	2.3
7/7/98	TL-3-PKF-04	PKF	TL-3	39	0.69	M	75.4	2

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Table B-3. Bird liver data.

DATE	SAMPLE ID	LOCATION	WET WT (G)	%MOIST	Se (ppm dry)	Se (ppm wet)
7/9/97	TL-RWBB-1	TL	0.909	69.2	5.7	1.76
7/9/97	TL-RWBB-2	TL	1.176	71.4	6.2	1.77
7/9/97	TL-RWBB-3	TL	0.947	69.5	7.5	2.29
7/9/97	FW-RWBB-4	FW	0.83	63.7	9.6	3.48
7/9/97	FW-RWBB-5	FW	0.882	69.7	7.5	2.27
7/9/97	FW-RWBB-6	FW	1.193	68.7	17	5.32
7/9/97	FW-RWBB-7	FW	0.809	68.9	8.2	2.55
7/9/97	FW-RWBB-8	FW	1.238	70.1	19	5.68
7/9/98	RWBB6-TBL-98	TL	0.621	68.8	8.6	2.68
7/9/98	RWBB7-TBL-98	TL	0.901	68.9	8.5	2.64
7/9/98	RWBB8-TBL-98	TL	1.146	72.4	6	1.66
7/9/98	RWBB9-TBL-98	TL	0.657	67.1	8	2.63
7/9/98	RWBB10-TBL-98	TL	0.734	68.4	7.4	2.34
7/9/98	RWBB1-FWP-98	FW	0.959	66.7	6.7	2.23
7/9/98	RWBB2-FWP-98	FW	0.709	67.1	6	1.97
7/9/98	RWBB3-FWP-98	FW	0.727	66	5.6	1.9
7/9/98	RWBB4-FWP-98	FW	1.371	70.4	6.1	1.81
7/9/98	RWBB5-FWP-98	FW	0.651	68.4	11	3.47

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Table B-4. Bird food item data.

DATE	SAMPLE ID	LOCATION	WET WT (G)	%MOIST	Se (ppm dry wt)
7/9/97	TL-RWBB-1	TL	0.182	30.2	0.37
7/9/97	TL-RWBB-2	TL	0.704	58.2	0.61
7/9/97	TL-RWBB-3	TL	0.058	34.5	2.3
7/9/97	FW-RWBB-4	FW	0.234	42.7	1.5
7/9/97	FW-RWBB-5	FW	0.52	57.1	0.39
7/9/97	FW-RWBB-6	FW	0.443	58.5	2.8
7/9/97	FW-RWBB-7	FW	0.641	59	1.1
7/9/97	FW-RWBB-8	FW	0.512	57.6	4.2

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Table B-5. Area VIII fish data.

DATE	SAMPLE ID	SPECIES	LOC	L (mm)	Wet wt (g)	SEX	%MOIST	Se (ppm dry wt)
6/10/97	RC8-P-RRP-01	RRP	8-P	45	1.517		76.4	4.4
6/10/97	RC8-P-RRP-02	RRP	8-P	51	2.799		71.1	5.6
6/10/97	RC8-P-RRP-03	RRP	8-P	50	2.365		72.5	5.8
6/10/97	RC8-P-RRP-04	RRP	8-P	40	1.209		73.3	5.5
6/10/97	RC8-P-RRP-05	RRP	8-P	41	1.32		73.4	5.2
6/10/97	RC8-P-RRP-06	RRP	8-P	44	1.985		72.9	5.3
6/10/97	RC8-P-RRP-07	RRP	8-P	41	1.414		72.3	4.6
6/10/97	RC8-P-RRP-08	RRP	8-P	46	1.737		73.6	5.7
6/10/97	RC8-P-RRP-09	RRP	8-P	40	1.263		69.6	3.8
6/10/97	RC8-P-RRP-10	RRP	8-P	35	1.071		71.6	5
6/10/97	RC8-P-PKF-01	PKF	8-P	63	3.233	M	71.6	2.9
6/10/97	RC8-P-PKF-02	PKF	8-P	66	4.33	F	73	2.7
6/10/97	RC8-P-PKF-03	PKF	8-P	69	4.761	M	71.6	2.6
6/10/97	RC8-P-PKF-04	PKF	8-P	63	3.616	M	72.5	2.5
6/10/97	RC8-P-PKF-05	PKF	8-P	57	2.785	M	76.8	5.4
6/10/97	RC8-P-PKF-06	PKF	8-P	49	1.473	F	76.4	2.8
6/10/97	RC8-P-PKF-07	PKF	8-P	57	2.663	M	75.1	2.8
6/10/97	RC8-P-PKF-08	PKF	8-P	70	4.192	F	72.6	2.6
6/10/97	RC8-P-PKF-09	PKF	8-P	51	1.917	F	75.2	3.3
6/10/97	RC8-P-PKF-10	PKF	8-P	41	0.829	F	75.2	3.5
6/10/97	RC8-D-RRP-01	RRP	8-D	46	1.95		77.5	4.7
6/10/97	RC8-D-RRP-02	RRP	8-D	46	2.232		75.6	3.7
6/10/97	RC8-D-RRP-03	RRP	8-D	52	3.275		71.8	2.1
6/10/97	RC8-D-RRP-04	RRP	8-D	43	1.837		74.8	4.2
6/10/97	RC8-D-RRP-05	RRP	8-D	43	1.706		75	3.2
6/10/97	RC8-D-RRP-06	RRP	8-D	42	1.638		76.7	3.7
6/10/97	RC8-D-RRP-07	RRP	8-D	46	1.927		77.3	2.7
6/10/97	RC8-D-RRP-08	RRP	8-D	46	1.736		75.9	2.8
6/10/97	RC8-D-RRP-09	RRP	8-D	45	1.923		73.7	7.6
6/10/97	RC8-D-RRP-10	RRP	8-D	49	2.322	M	74.8	6.5
6/10/97	RC8-D-PKF-01	PKF	8-D	72	3.858	F	78	3.3
6/10/97	RC8-D-PKF-02	PKF	8-D	51	1.561	M	71.8	2.1
6/10/97	RC8-D-PKF-03	PKF	8-D	55	1.893	F	72.1	2.5
6/10/97	RC8-D-PKF-04	PKF	8-D	61	2.503	M	72.5	3
6/10/97	RC8-D-PKF-05	PKF	8-D	58	2.463	M	72.6	3
6/10/97	RC8-D-PKF-06	PKF	8-D	51	1.639	F	77.6	2.7
6/10/97	RC8-D-PKF-07	PKF	8-D	53	1.993	M	69.6	2.6
6/10/97	RC8-D-PKF-08	PKF	8-D	53	2.063	M	68.5	2.3
6/10/97	RC8-D-PKF-09	PKF	8-D	36	0.48	F	77.2	4.3
6/10/97	RC8-D-PKF-10	PKF	8-D	46	1.286	M	73.2	3
6/10/97	RC8-U-RRP-01	RRP	8-U	54	3.47		73	5.7
6/10/97	RC8-U-RRP-02	RRP	8-U	55	3.672		71.3	5.8

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DATE	SAMPLE ID	SPECIES	LOC	L (mm)	Wet wt (g)	SEX	%MOIST	Se (ppm dry wt)
6/10/97	RC8-U-RRP-03	RRP	8-U	36	1.026		73.2	5.32
6/10/97	RC8-U-RRP-04	RRP	8-U	35	2.189		73.2	5.8
6/10/97	RC8-U-RRP-05	RRP	8-U	50	2.892		77	6.5
6/10/97	RC8-U-RRP-06	RRP	8-U	39	0.9		72.6	5
6/10/97	RC8-U-RRP-07	RRP	8-U	40	1.329		75.2	6.3
6/10/97	RC8-U-RRP-08	RRP	8-U	41	1.527		72.7	4.5
6/10/97	RC8-U-RRP-09	RRP	8-U	41	1.454		72	4.7
6/10/97	RC8-U-RRP-10	RRP	8-U	40	1.458		71.8	4.7
7/6/98	RC8-P-RRP-01	RRP	8-P	48	2.725		67	4.3
7/6/98	RC8-P-RRP-02	RRP	8-P	52	3.635		69.6	5.5
7/6/98	RC8-P-RRP-03	RRP	8-P	48	1.089		71.5	3.6
7/6/98	RC8-P-RRP-04	RRP	8-P	41	0.571		75.5	3.3
7/6/98	RC8-P-RRP-05	RRP	8-P	48	2.455		71	6.3
7/6/98	RC8-P-RRP-06	RRP	8-P	38	1.225		68.3	5.1
7/6/98	RC8-P-RRP-07	RRP	8-P	32	0.341		75.2	4.6
7/6/98	RC8-P-RRP-08	RRP	8-P	49	2.439		72	5.2
7/6/98	RC8-P-RRP-09	RRP	8-P	30	0.566		74.5	7.2
7/6/98	RC8-P-RRP-10	RRP	8-P	41	1.363		68	3.6
7/6/98	RC8-P-PKF-01	PKF	8-P	53	1.839	F	77.6	4.4
7/6/98	RC8-P-PKF-02	PKF	8-P	39	0.613	M	75.8	3.7
7/6/98	RC8-P-PKF-03	PKF	8-P	51	1.72	F	76.8	4.1
7/6/98	RC8-P-PKF-04	PKF	8-P	36	0.518	M	77.2	4.6
7/6/98	RC8-P-PKF-05	PKF	8-P	36	0.505	F	73.9	4.7
7/6/98	RC8-P-PKF-06	PKF	8-P	36	0.541	M	75.9	4.6
7/6/98	RC8-P-PKF-07	PKF	8-P	36	0.509	M	77.1	3.8
7/6/98	RC8-P-PKF-08	PKF	8-P	31	0.37	M	80.3	4.7
7/6/98	RC8-P-PKF-09	PKF	8-P	30	0.356	F	76.9	5.2
7/6/98	RC8-P-PKF-10	PKF	8-P	30	0.301	F	78.9	6.2
7/6/98	RC8-D-RRP-01	RRP	8-D	48	2.398		67.2	3
7/6/98	RC8-D-RRP-02	RRP	8-D	48	2.373		67.9	2.8
7/6/98	RC8-D-RRP-03	RRP	8-D	42	1.686		68.3	3
7/6/98	RC8-D-RRP-04	RRP	8-D	43	2.319		67	2.5
7/6/98	RC8-D-RRP-05	RRP	8-D	44	2.148		71.7	2.7
7/6/98	RC8-D-RRP-06	RRP	8-D	47	2.095		73	3.6
7/6/98	RC8-D-RRP-07	RRP	8-D	38	0.729		75.4	3.8
7/6/98	RC8-D-RRP-08	RRP	8-D	39	1.274		68.7	3.5
7/6/98	RC8-D-RRP-09	RRP	8-D	51	2.401		67.3	4.4
7/6/98	RC8-D-RRP-10	RRP	8-D	41	1.691		68	2.9
7/6/98	RC8-D-PKF-01	PKF	8-D	63	2.053	M	78.6	4.2
7/6/98	RC8-D-PKF-02	PKF	8-D	49	1.557	M	70.2	2.8
7/6/98	RC8-D-PKF-03	PKF	8-D	51	1.586	F	76.1	3.1
7/6/98	RC8-D-PKF-04	PKF	8-D	51	1.747	M	74.8	2.9
7/6/98	RC8-D-PKF-05	PKF	8-D	41	0.896	M	70.8	2.4
7/6/98	RC8-D-PKF-06	PKF	8-D	51	1.512	M	72.5	2.2

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DATE	SAMPLE ID	SPECIES	LOC	L (mm)	Wet wt (g)	SEX	%MOIST	Se (ppm dry wt)
7/6/98	RC8-D-PKF-07	PKF	8-D	40	0.912	F	76	3.3
7/6/98	RC8-D-PKF-08	PKF	8-D	51	1.707	M	74.9	3.8
7/6/98	RC8-D-PKF-09	PKF	8-D	55	1.553	M	74.1	3.1
7/6/98	RC8-D-PKF-10	PKF	8-D	50	1.224	M	73.6	3.2
7/6/98	RC8-U-RRP-01	RRP	8-U	28	0.265		73.8	4.9
7/6/98	RC8-U-RRP-02	RRP	8-U	42	1.283		75.5	3.8
7/6/98	RC8-U-RRP-03	RRP	8-U	43	0.895		77.3	3.2
7/6/98	RC8-U-RRP-04	RRP	8-U	29	0.322		71.5	3.8
7/6/98	RC8-U-RRP-05	RRP	8-U	44	0.809		74.8	4
7/6/98	RC8-U-RRP-06	RRP	8-U	43	0.97		74.6	4.3
7/6/98	RC8-U-RRP-07	RRP	8-U	32	0.393		74.8	4.6
7/6/98	RC8-U-RRP-08	RRP	8-U	43	0.957		73.7	3.8
7/6/98	RC8-U-RRP-09	RRP	8-U	41	0.881		74.6	3.8
7/6/98	RC8-U-RRP-10	RRP	8-U	28	0.364		77.2	5.9

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Table B-6. Area X fish data.

DATE	SAMPLE ID	SPECIES	L (mm)	Wet wt. (g)	Sex	%Moist	Se (ppm dry wt)
7/7/98	RC10-RRP-01	RRP	53	3.59		68.2	18
7/7/98	RC10-RRP-02	RRP	49	2.767		70.6	20
7/7/98	RC10-RRP-03	RRP	43	1.575		70.8	19
7/7/98	RC10-RRP-04	RRP	41	1.738		72	18
7/7/98	RC10-PKF-01	PKF	40	0.748	M	72.5	23
7/7/98	RC10-PKF-02	PKF	38	0.488	F	74.1	27
7/7/98	RC10-PKF-03	PKF	30	0.343	M	71.9	26
7/7/98	RC10-RS-01	RS	57	2.664		75.5	25
7/7/98	RC10-RS-02	RS	59	2.198		78.3	28
7/7/98	RC10-RS-03	RS	51	1.678		77.6	29
7/7/98	RC10-H-01	HYBOG	59	2.753		73.8	28
7/7/98	RC10-H-02	HYBOG	60	2.547		75.7	28
7/7/98	RC10-H-03	HYBOG	62	2.924		71.7	28